



Environment  
Canada

Environmental  
Protection  
Service

Environnement  
Canada

Service de la  
protection de  
l'environnement

CA 1 EP53082E06



# Trace Elements in Canadian Coals

Earth Sciences Library

Economic and Technical Review  
Report EPS 3-AP-82-6

Air Pollution Control Directorate  
August 1982

Canada



## ENVIRONMENTAL PROTECTION SERVICE REPORT SERIES

Economic and Technical Review Reports relate to state-of-the-art reviews, library surveys, industrial inventories, and their associated recommendations where no experimental work is involved. These reports are undertaken either by an outside agency or by the staff of the Environmental Protection Service.

Other categories in the EPS series include such groups as Regulations, Codes, and Protocols; Policy and Planning; Technology Development; Surveillance; Training Manuals; Briefs and Submissions to Public Inquiries; and, Environmental Impact and Assessment.

Inquiries pertaining to Environmental Protection Service Reports should be directed to the Environmental Protection Service, Environment Canada, Ottawa, Ontario, Canada, K1A 1C8.

## TRACE ELEMENTS IN CANADIAN COALS

F. Landheer, H. Dibbs and J. Labuda  
Engineering Assessment Branch  
Air Pollution Control Directorate

Report EPS 3-AP-82-6  
August 1982





**ABSTRACT**

In this report, the concentrations of 42 trace elements in coal are given for 38 samples of coal obtained from coal fields across Canada. Neutron activation analysis was the principal analytical method used in the study; however, plasma emission spectrometry and flame atomic absorption spectrometry were also used. For some of the trace elements, the accuracy of the three analytical methods was checked by using two standard reference coals supplied by the United States National Bureau of Standards.

## LIST OF TABLES

| Table |                                                                                                                                                         | Page |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1     | PROXIMATE AND ULTIMATE ANALYSES AND MERCURY CONTENT OF COALS                                                                                            | 5    |
| 2     | ELEMENTS DETERMINED BY EACH OF THE ANALYTICAL METHODS                                                                                                   | 7    |
| 3     | CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS                                                            | 8    |
| 4     | CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY                                                  | 18   |
| 5     | CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY ATOMIC ABSORPTION SPECTROMETRY                                                | 24   |
| 6     | COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY                       | 25   |
| 7     | COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY PLASMA EMISSION SPECTROMETRY AND ATOMIC ABSORPTION SPECTROMETRY                    | 29   |
| 8     | COAL IDENTIFICATION NUMBERS FOR SAMPLE DISSOLUTION TECHNIQUES                                                                                           | 35   |
| 9     | RESULTS OF NEUTRON ACTIVATION ANALYSIS DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632    | 38   |
| 10    | RESULTS OF NEUTRON ACTIVATION ANALYSIS DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632a   | 39   |
| 11    | RESULTS OF ATOMIC ABSORPTION SPECTROMETRY DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632 | 40   |
| 12    | RESULTS OF PLASMA EMISSION SPECTROMETRY DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632   | 41   |

## 1 INTRODUCTION

Canada's coal reserves are estimated to be about 120 billion tons, of which about six billion tons are considered to be economically recoverable. With such large reserves, particularly when compared to the much more limited reserves of indigenous oil and natural gas, it is anticipated that coal will play an increasingly important role in Canada's future energy supply. Currently, Canadian coal production is about 30 million tons per year, and this is expected to increase to about 100 million tons annually by the year 2 000.

However, in spite of its large reserves, coal is recognized environmentally as a "dirty" fuel, and the development of efficient, cost-effective control measures for sulphur dioxide, nitrogen oxides, and particulate emissions from coal combustion have, in recent years, been the focus of major national and international efforts and concerns. In addition, it is anticipated that future concerns related to coal usage could well be directed to the emission to the environment of trace elements present in coal during various stages of the coal extraction/utilization cycle, i.e., mining, preparation, transportation and conversion or combustion. Currently, any attempt to assess the significance of these emissions is severely limited by a lack of information on the concentration of trace elements in Canadian coals and, as a consequence, this study was undertaken as a first, systematic effort to provide such information for representative coal deposits across Canada. In doing so, it is recognized that coal is inherently an inhomogeneous substance and that much additional work will be required to characterize more fully the trace element concentrations; nevertheless, it is hoped that the present initial survey will provide useful insight and guidance to those involved in this area.

## 2 COAL SAMPLES AND ANALYTICAL PROCEDURES

The coal samples used in this study were provided by the Fuels Research Laboratories, Department of Energy, Mines and Resources, Ottawa, and had been collected and prepared according to standard methods. The samples are representative of coal deposits across Canada, and range in rank from lignite to high-volatile bituminous coal. Proximate and ultimate analyses of the coals are given in Table 1, together with the mercury content of some of the coals (1).

For this investigation, each coal sample (which was received pre-ground to about 100-mesh) was divided into three parts; one part was used "as received" for analysis



by non-destructive or instrumental neutron activation analysis (NAA); the second part was dissolved (see Appendix 1 for destructive dissolution methods) and portions of the solution were used for analysis by plasma emission spectrometry (PES) and by flame atomic absorption spectrometry (AAS); the third part was retained for future analyses and reference purposes.

The NAA determinations were performed by Commercial Products, Atomic Energy of Canada Ltd., Ottawa, using an AECL Slowpoke 2 reactor as a neutron source (thermal neutron flux,  $5 \times 10^{11} \text{ n/cm}^2\text{-s}$ ). With the exception of uranium, which was determined by delayed neutron counting, the concentrations of all the trace elements were measured by gamma-ray spectrometry using solutions containing the elements being determined as reference standards. The errors quoted for the NAA measurements are the sum of a 5% error resulting from neutron flux and counting geometry variations, weighing errors, etc., plus a one-standard-deviation counting-error due to the statistics of radioactive decay.

The PES determinations were made by Barringer Magenta Research Ltd., Rexdale, Ontario, using an analytical procedure similar to that developed by the United States Environmental Protection Agency (2).

The AAS measurements were made by the Laboratory Services Division, Air Pollution Control Directorate, Environment Canada, who were also responsible for preparing the solutions for the PES measurements.

A summary of the elements determined by each of the analytical methods is given in Table 2.

To check on the validity and applicability of these analytical techniques for the determination of trace elements in coal, two standard reference coals (NBS 1632 and 1632a) from the National Bureau of Standards (NBS) were used as comparators for 22 of the trace elements determined in this study. A detailed comparison of the analytical data is given in Appendix 2, and it may be concluded that the three analytical techniques gave results that were in acceptable agreement with the NBS certified trace element concentrations.

### 3 RESULTS

The concentrations of trace elements in the 38 coal samples analyzed in this study are given in Tables 3, 4 and 5, for measurements made by NAA, PES and AAS, respectively. It will be noted from these tables that not all of the 42 elements reported



were measured independently by each of the three analytical methods; this was due primarily to the characteristics of the methods used. Thus, 25 of the elements were determined by only one method (NAA or PES), 15 elements were determined by two methods, and two elements were determined by all three methods. For those elements determined independently by two techniques (NAA and PES, or PES and AAS), an element-by-element comparison of the analytical results is given in Tables 6 and 7; in general, satisfactory agreement was found between the methods.

The trace element concentration data given in Tables 3-5 indicate that the concentration of a given element can vary widely from sample to sample and that only general observations can be made concerning the concentration of a particular element in different coals across Canada. This situation is exemplified by the following comments on some of the elements determined in the present study.

- Arsenic     For the 31 coals from Western Canada (Saskatchewan, Alberta and British Columbia), the arsenic concentration in all but two of the coals (at 11.6 and 13 ppm) was less than 10 ppm, and the majority of the coals had arsenic concentrations below 2 ppm. In contrast, all but one of the Eastern coals (at 4.3 ppm) had arsenic concentrations above 10 ppm, and the arsenic concentration in the two New Brunswick coals was 131 and 311 ppm.
- Beryllium   The concentration of beryllium showed no significant variation among the coals and had an average value of about 0.9 ppm.
- Boron        Among the Western coals, those from Saskatchewan, on average, had the highest boron concentration (about 1250 ppm) and those from Alberta the lowest (about 860 ppm). Results were obtained for only two Nova Scotia coals at 119 and 1872 ppm.
- Cadmium     Relatively few measurements were obtained for cadmium and the values showed no dependence on the coal source; they ranged from 6.6 to 8.8 ppm.
- Lead          With the exception of three samples from Nova Scotia (at 52.6, 52.7 and 55.4 ppm), all the samples contained less than 20 ppm lead, with most containing between 2 and 10 ppm. In general the coals from British Columbia and New Brunswick had the lowest lead concentrations.
- Selenium     The two coals from New Brunswick contained 4.9 and 10.9 ppm. All the other coals contained less than 4 ppm selenium.

- Thorium The thorium content showed no marked dependence on coal source and nearly all the samples contained between 1 to 3.5 ppm. Two Nova Scotia coals (0.2 and 0.3 ppm) and two Alberta coals (4.8 and 6.17 ppm) were outside this range.
- Uranium The uranium content of the coals was generally less than 2 ppm. However, one coal from Nova Scotia contained 2.2 ppm and four coals from Saskatchewan ranged from 2.12 to 2.91 ppm.
- Vanadium The vanadium content was generally lowest for Saskatchewan coals (5 to 17.5 ppm) and highest for British Columbia coals (18.6 to 108 ppm). The Eastern coals had an average vanadium concentration of about 25 ppm.

#### 4 CONCLUSIONS AND RECOMMENDATIONS

The concentrations of 42 trace elements in coal have been determined for 38 samples of coal taken primarily from commercial coal operations across Canada. Since only one sample from each source was analyzed, it is recommended that similar analyses should be undertaken for other samples from the same deposits in order to confirm the validity of the present results and also the regional concentration differences shown by a number of the trace elements. In the meantime, those involved in the pollution assessment and control fields will be able to use the data given in this report to estimate the potential environmental impacts resulting from the presence of various trace elements in Canadian coals during all phases of the coal extraction/utilization cycle.

#### REFERENCES

1. Private communication with W.J. Montgomery, Department of Energy, Mines and Resources, Ottawa.



TABLE 1 PROXIMATE AND ULTIMATE ANALYSES AND MERCURY CONTENT OF COALS

| Company             | Field       | Mine          | Proximate Analysis (Air dried) |          |                      |                   | Ultimate Analysis (Air dried) |               |              |               |          |             | Calorific Value MJ/kg | Mercury ppm |  |
|---------------------|-------------|---------------|--------------------------------|----------|----------------------|-------------------|-------------------------------|---------------|--------------|---------------|----------|-------------|-----------------------|-------------|--|
|                     |             |               | Moisture wt %                  | Ash wt % | Volatile Matter wt % | Fixed Carbon wt % | Carbon wt %                   | Hydrogen wt % | Sulphur wt % | Nitrogen wt % | Ash wt % | Oxygen wt % |                       |             |  |
| NOVA SCOTIA         |             |               |                                |          |                      |                   |                               |               |              |               |          |             |                       |             |  |
| River Herbert       | Joggins     | River Herbert | 1.71                           | 32.37    | 27.34                | 38.58             | 53.58                         | 3.56          | 4.10         | 1.20          | 32.37    | 3.48        | 21.67                 | 0.29        |  |
| Thorburn            | Pictou      | Acadia        | 1.29                           | 28.23    | 22.91                | 47.57             | -                             | -             | (0.97)       | -             | (28.23)  | -           | 23.47                 | -           |  |
| Devco               | Sydney      | Lingan        | 1.02                           | 3.16     | 34.35                | 61.47             | -                             | -             | (1.04)       | -             | (3.16)   | -           | -                     | -           |  |
| Devco               | Sydney      | No. 26        | 0.94                           | 2.18     | 33.70                | 63.18             | -                             | -             | (0.79)       | -             | (2.18)   | -           | -                     | -           |  |
| Devco               | Sydney      | Prince        | 1.79                           | 18.80    | 30.79                | 48.62             | 62.42                         | 4.34          | 5.03         | 1.28          | 18.80    | 6.34        | -                     | -           |  |
| NEW BRUNSWICK       |             |               |                                |          |                      |                   |                               |               |              |               |          |             |                       |             |  |
| N.B. Electric Power | Minto       | Minto         | 1.38                           | 18.15    | 32.32                | 48.15             | 65.39                         | 4.37          | 7.10         | 0.97          | 18.15    | 2.64        | 28.24                 | 0.60        |  |
| N.B. Coal           | Minto       | Minto         | 0.67                           | 23.77    | -                    | -                 | 58.02                         | 3.73          | 10.66        | 0.74          | 23.77    | 2.41        | -                     | 1.23        |  |
| SASKATCHEWAN        |             |               |                                |          |                      |                   |                               |               |              |               |          |             |                       |             |  |
| Manitoba Power      | Estevan     | Estevan       | 20.95                          | 11.31    | 32.17                | 35.57             | 48.69                         | 3.10          | 0.47         | 0.81          | 11.31    | 14.67       | 18.66                 | 0.07        |  |
| M&S Coal            | Estevan     | Biertait      | 26.18                          | 11.64    | 29.00                | 33.18             | -                             | -             | (0.36)       | -             | (11.64)  | -           | 17.87                 | -           |  |
| M&S Coal            | Estevan     | Boundary Dam  | 21.28                          | 13.61    | 29.55                | 35.56             | 46.82                         | 3.04          | 0.29         | 0.95          | 13.61    | 14.01       | 17.91                 | 0.07        |  |
| Sask. Power Corp.   | Estevan     | Boundary Dam  | 19.52                          | 13.46    | 31.34                | 35.68             | 48.32                         | 3.18          | 0.50         | 0.92          | 13.46    | 14.10       | 18.83                 | 0.06        |  |
| Sask. Power Corp.   | Estevan     | Queen Eliz.   | 19.88                          | 10.03    | 31.18                | 38.91             | 51.96                         | 2.98          | 0.41         | 1.13          | 10.03    | 13.61       | 19.83                 | 0.06        |  |
| Manalta             | Estevan     | Klimax        | 11.96                          | 13.57    | 32.98                | 41.49             | 54.24                         | 3.37          | 0.64         | 0.96          | 13.57    | 15.26       | 20.92                 | 0.11        |  |
| Poplar River        | Core Sample | Exploratory   | 21.68                          | 18.19    | 29.27                | 30.86             | 42.21                         | 2.81          | 0.65         | 0.60          | 18.19    | 13.86       | 15.86                 | -           |  |
| Poplar River        | Core Sample | Exploratory   | 12.91                          | 17.30    | 33.23                | 36.56             | 49.11                         | 3.21          | 0.60         | 0.66          | 17.30    | 16.21       | 18.45                 | -           |  |

Data given in parentheses under Ultimate Analysis are the only values available for these coals.

TABLE 1 PROXIMATE AND ULTIMATE ANALYSES AND MERCURY CONTENT OF COALS (cont'd.)

| Company            | Field         | Mine                | Proximate Analysis (Air dried) |          |                      |                   |             | Ultimate Analysis (Air dried) |              |               |          |             | Calorific Value MJ/kg | Mercury ppm |
|--------------------|---------------|---------------------|--------------------------------|----------|----------------------|-------------------|-------------|-------------------------------|--------------|---------------|----------|-------------|-----------------------|-------------|
|                    |               |                     | Moisture wt %                  | Ash wt % | Volatile Matter wt % | Fixed Carbon wt % | Carbon wt % | Hydrogen wt %                 | Sulphur wt % | Nitrogen wt % | Ash wt % | Oxygen wt % |                       |             |
| ALBERTA            |               |                     |                                |          |                      |                   |             |                               |              |               |          |             |                       |             |
| Manalta            | Sheerness     | Roselyn             | 23.73                          | 11.20    | 31.74                | 33.33             | -           | -                             | (0.41)       | -             | (11.20)  | -           | 18.58                 | -           |
| McIntyre           | Grande Cache  | McIntyre            | 0.37                           | 7.27     | 19.21                | 73.15             | 83.37       | 4.31                          | 0.41         | 1.09          | 7.27     | 3.18        | 33.43                 | 0.13        |
| McIntyre           | Grande Cache  | McIntyre            | 0.65                           | 7.42     | 20.14                | 71.79             | 82.76       | 4.38                          | 0.44         | 1.08          | 7.42     | 3.27        | 33.43                 | 0.10        |
| Luscar Coal        | Castor        | Diplomat            | 22.35                          | 7.34     | 30.72                | 39.59             | 52.06       | 3.34                          | 0.41         | 1.17          | 7.34     | 13.33       | 20.42                 | 0.02        |
| Manalta            | Castor        | Vesta               | 20.45                          | 8.68     | 30.16                | 40.71             | 51.81       | 3.32                          | 0.33         | 1.17          | 8.68     | 14.24       | 20.33                 | 0.03        |
| Century Coals      | Drumheller    | Atlas               | 16.73                          | 9.06     | 30.29                | 43.92             | 55.09       | 3.40                          | 0.46         | 1.25          | 9.06     | 14.01       | 21.50                 | 0.04        |
| Manalta            | Pembina       | Highvale            | 8.39                           | 15.51    | 30.05                | 46.05             | 56.39       | 3.37                          | 0.19         | 0.06          | 15.51    | 16.09       | 21.84                 | 0.07        |
| Manalta            | Pembina       | Whitewood           | 8.97                           | 13.52    | 31.36                | 46.15             | 56.88       | 3.37                          | 0.29         | 0.75          | 13.52    | 16.22       | 22.18                 | 0.44        |
| Sundance Mines     | Edmonton      | Sundance            | 13.61                          | 13.84    | 29.12                | 43.43             | 54.89       | 2.19                          | 0.21         | 0.67          | 13.84    | 14.60       | 21.00                 | -           |
| Imperial Oil       | Edmonton      | Judy Creek          | 16.24                          | 24.98    | 25.90                | 32.88             | 41.23       | 1.44                          | 0.29         | 0.45          | 24.98    | 15.37       | 15.82                 | -           |
| Coleman Collieries | Crowsnest     | Vicary Creek        | 0.84                           | 10.18    | 23.58                | 65.40             | 79.02       | 4.47                          | 0.36         | 1.23          | 10.18    | 3.90        | 31.63                 | -           |
| Coleman Collieries | Crowsnest     | Tent Mountain       | 0.97                           | 12.00    | 23.47                | 63.26             | 76.55       | 4.31                          | 0.35         | 1.03          | 12.00    | 4.79        | 30.75                 | 0.07        |
| Cardinal River     | Mountain Park | Cardinal River      | 0.95                           | 9.16     | 26.17                | 63.72             | 79.68       | 4.63                          | 0.26         | 1.09          | 9.16     | 4.23        | 32.13                 | 0.10        |
| BRITISH COLUMBIA   |               |                     |                                |          |                      |                   |             |                               |              |               |          |             |                       |             |
| B.C. Hydro         | Ashcroft      | Hat Creek           | 18.18                          | 44.67    | 22.41                | 14.74             | 23.36       | 2.09                          | 0.45         | 0.95          | 44.67    | 10.30       | 8.33                  | -           |
| B.C. Hydro         | Ashcroft      | Hat Creek*          | 3.35                           | 22.79    | 34.76                | 39.10             | 48.72       | 3.32                          | 1.10         | 0.87          | 22.79    | 19.85       | 19.88                 | -           |
| Tulameen           | Tulameen      | Tulameen            | 7.92                           | 15.74    | 30.44                | 45.90             | 60.04       | 3.12                          | 1.03         | 1.03          | 15.74    | 11.12       | 23.68                 | -           |
| B.P. Canada        | Chetwynd      | Sukunka             | 1.07                           | 15.63    | 22.15                | 61.15             | 75.05       | 4.20                          | 0.59         | 1.14          | 15.63    | 2.32        | 30.33                 | -           |
| Denison Coal       | E. Kootenay   | Denison             | 0.65                           | 6.94     | 24.10                | 68.31             | 82.47       | 4.56                          | 0.30         | 1.17          | 6.94     | 3.91        | 33.18                 | -           |
| Byron Creek        | E. Kootenay   | Byron Creek         | 1.79                           | 14.98    | 23.92                | 59.31             | 72.14       | 4.09                          | 0.20         | 1.07          | 14.98    | 5.64        | 29.16                 | -           |
| Kaiser Resources   | E. Kootenay   | Kaiser (Seam No. 7) | 1.28                           | 9.52     | 19.93                | 69.27             | 80.40       | 4.33                          | 0.52         | 1.09          | 9.52     | 2.86        | 32.22                 | -           |
| Kaiser Resources   | E. Kootenay   | Elk View            | 2.69                           | 14.08    | 20.66                | 62.57             | 73.31       | 3.76                          | 0.27         | 1.09          | 14.08    | 4.80        | 29.04                 | 0.07        |
| Kaiser Resources   | E. Kootenay   | Elk View*           | 1.26                           | 9.92     | 20.14                | 68.68             | 80.27       | 4.44                          | 0.34         | 1.17          | 9.92     | 2.60        | 32.64                 | 0.06        |
| Fording Coal       | E. Kootenay   | Fording             | 1.67                           | 10.04    | 21.37                | 66.92             | 79.20       | 4.28                          | 0.39         | 1.07          | 10.04    | 3.25        | 31.67                 | 0.06        |

\* Clean coal samples



TABLE 2 ELEMENTS DETERMINED BY EACH OF THE ANALYTICAL METHODS

| Analytical Method | Aluminum | Antimony   | Arsenic   | Barium     | Beryllium | Boron    | Bromine   | Cadmium   | Calcium   | Cerium    | Chlorine  | Chromium   |
|-------------------|----------|------------|-----------|------------|-----------|----------|-----------|-----------|-----------|-----------|-----------|------------|
| NAA               | X        | X          | X         | X          | -         | -        | X         | -         | -         | X         | X         | X          |
| PES               | X        | -          | -         | X          | X         | X        | X         | X         | X         | -         | -         | X          |
| AAS               | -        | -          | -         | -          | -         | -        | -         | -         | -         | -         | -         | -          |
|                   | Cobalt   | Copper     | Europium  | Gadolinium | Hafnium   | Iodine   | Iron      | Lanthanum | Lead      | Magnesium | Manganese | Molybdenum |
| NAA               | X        | -          | X         | X          | X         | X        | X         | X         | -         | X         | X         | -          |
| PES               | X        | X          | -         | -          | -         | -        | X         | -         | X         | X         | X         | X          |
| AAS               | -        | X          | -         | -          | -         | -        | X         | X         | X         | X         | X         | -          |
|                   | Nickel   | Phosphorus | Potassium | Samarium   | Scandium  | Selenium | Silver    | Sodium    | Strontium | Tantalum  | Terbium   |            |
| NAA               | -        | -          | X         | X          | X         | X        | -         | X         | X         | X         | X         | X          |
| PES               | X        | X          | X         | -          | -         | -        | X         | X         | X         | -         | -         | -          |
| AAS               | -        | -          | -         | -          | -         | -        | -         | -         | -         | -         | -         | -          |
|                   | Thorium  | Titanium   | Uranium   | Vanadium   | Ytterbium | Zinc     | Zirconium |           |           |           |           |            |
| NAA               | X        | X          | X         | X          | -         | -        | -         |           |           |           |           |            |
| PES               | X        | X          | -         | -          | X         | X        | X         |           |           |           |           |            |
| AAS               | -        | -          | -         | -          | -         | -        | X         |           |           |           |           |            |

NAA - neutron activation analysis; used to analyze all coal samples  
PES - plasma emission spectrometry; used to analyze all coal samples  
AAS - atomic absorption spectrometry; used to analyze ten coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS

| Company              | Field       | Mine          | Aluminum<br>ppm | % Err. | Antimony<br>ppm | % Err. | Arsenic<br>ppm | % Err. | Barium<br>ppm | % Err. | Bromine<br>ppm | % Err. | Cerium<br>ppm | % Err. |
|----------------------|-------------|---------------|-----------------|--------|-----------------|--------|----------------|--------|---------------|--------|----------------|--------|---------------|--------|
| <b>NOVA SCOTIA</b>   |             |               |                 |        |                 |        |                |        |               |        |                |        |               |        |
| River Herbert        | Joggins     | River Herbert | 25 300          | 6      | 0.77            | 54     | 33.9           | 7      | < 200         | -      | 28.6           | 9      | 32.8          | 9      |
| Thorburn             | Pictou      | Acadia        | 43 400          | 6      | 0.69            | 48     | 10.0           | 8      | 259           | 26     | 9.29           | 13     | 21.55         | 10     |
| Devco                | Sydney      | Lingan        | 1 940           | 11     | 0.75            | 28     | 10.4           | 8      | < 70          | -      | 19.2           | 10     | 5.65          | 21     |
| Devco                | Sydney      | No. 26        | 2 690           | 9      | <0.3            | -      | 4.33           | 10     | < 60          | -      | 7.61           | 12     | 2.61          | 36     |
| Devco                | Sydney      | Prince        | 20 500          | 6      | 1.45            | 26     | 86.3           | 6      | 93.7          | 57     | 17.1           | 10     | 20.3          | 11     |
| <b>NEW BRUNSWICK</b> |             |               |                 |        |                 |        |                |        |               |        |                |        |               |        |
| N.B. Electric Power  | Minto       | Minto         | 10 100          | 6      | <0.8            | -      | 131            | 7      | < 100         | -      | < 0.6          | -      | 34.1          | 9      |
| N.B. Coal            | Minto       | Minto         | 10 700          | 7      | 5.01            | 12     | 311            | 6      | < 100         | -      | < 0.7          | -      | 34.55         | 9      |
| <b>SASKATCHEWAN</b>  |             |               |                 |        |                 |        |                |        |               |        |                |        |               |        |
| Manitoba Power       | Estevan     | Estevan       | 12 100          | 6      | 0.10            | 100    | 1.54           | 35     | 1 090         | 14     | < 3.0          | -      | 8.87          | 15     |
| M&S Coal             | Estevan     | Bienfait      | 11 800          | 7      | 0.49            | 51     | < 0.2          | -      | 1 120         | 11     | < 0.5          | -      | 5.53          | 20     |
| M&S Coal             | Estevan     | Boundary Dam  | 14 000          | 7      | 1.22            | 26     | < 0.3          | -      | 832           | 13     | < 0.5          | -      | 11.4          | 13     |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | 8 570           | 6      | 3.33            | 17     | 5.89           | 18     | 594           | 20     | < 3.0          | -      | 17.3          | 12     |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | 10 500          | 6      | <0.5            | -      | < 0.7          | -      | 462           | 25     | 1.29           | 71     | 7.69          | 15     |
| Manalta              | Estevan     | Klimax        | 14 000          | 6      | <0.5            | -      | 0.78           | 62     | 1 190         | 15     | 3.07           | 43     | 6.87          | 17     |
| Poplar River         | Core Sample | Exploratory   | 22 400          | 6      | 2.67            | 15     | 3.41           | 13     | 675           | 23     | < 1.0          | -      | 10.5          | 15     |
| Poplar River         | Core Sample | Exploratory   | 18 500          | 6      | <0.5            | -      | 4.82           | 14     | 413           | 33     | 1.87           | 40     | 11.2          | 14     |



TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company                 | Field         | Mine                | Aluminum<br>ppm | % Err. | Antimony<br>ppm | % Err. | Arsenic<br>ppm | % Err. | Barium<br>ppm | % Err. | Bromine<br>ppm | % Err. | Cerium<br>ppm | % Err. |
|-------------------------|---------------|---------------------|-----------------|--------|-----------------|--------|----------------|--------|---------------|--------|----------------|--------|---------------|--------|
| <b>ALBERTA</b>          |               |                     |                 |        |                 |        |                |        |               |        |                |        |               |        |
| Manalta                 | Sheerness     | Roselyn             | 13 200          | 7      | <0.4            | -      | 1.14           | 58     | 166           | 34     | <0.5           | -      | 9.14          | 13     |
| McIntyre                | Grande Cache  | McIntyre            | 10 800          | 7      | 0.42            | 59     | 6.07           | 12     | 301           | 20     | 10.8           | 14     | 8.18          | 17     |
| McIntyre                | Grande Cache  | McIntyre            | 12 100          | 6      | 0.29            | 100    | <0.4           | -      | 363           | 32     | 4.47           | 23     | 10.7          | 14     |
| Luscar Coal             | Castor        | Diplomat            | 7 640           | 6      | <0.3            | -      | <1.0           | -      | 308           | 29     | <2.0           | -      | 4.29          | 24     |
| Manalta                 | Castor        | Vesta               | 10 100          | 6      | <0.5            | -      | <1.0           | -      | 558           | 20     | <2.0           | -      | 2.31          | 36     |
| Century Coals           | Drumheller    | Atlas               | 12 800          | 6      | 0.93            | 24     | <0.9           | -      | 395           | 29     | 1.70           | 68     | 11.1          | 12     |
| Manalta                 | Pembina       | Highvale            | 20 700          | 6      | <1.0            | -      | 1.09           | 36     | 617           | 23     | <2.0           | -      | 14.8          | 11     |
| Manalta                 | Pembina       | Whitewood           | 15 300          | 6      | <1.0            | -      | 2.36           | 14     | 264           | 44     | <1.0           | -      | 11.9          | 12     |
| Sundance Mines          | Edmonton      | Sundance            | 14 700          | 6      | 0.29            | 76     | 0.62           | 67     | 570           | 23     | 10.7           | 17     | 18.2          | 10     |
| Imperial Oil            | Edmonton      | Judy Creek          | 20 500          | 6      | 0.61            | 51     | 11.65          | 10     | 623           | 24     | 16.21          | 12     | 27.12         | 9      |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | 16 100          | 6      | 1.04            | 32     | <0.3           | -      | 719           | 12     | <0.5           | -      | 12.29         | 13     |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | 13 000          | 6      | 1.47            | 32     | 0.96           | 21     | 282           | 38     | <1.0           | -      | 10.5          | 16     |
| Cardinal River          | Mountain Park | Cardinal River      | 7 520           | 6      | 0.47            | 57     | <0.6           | -      | 473           | 23     | 1.71           | 45     | 9.11          | 15     |
| <b>BRITISH COLUMBIA</b> |               |                     |                 |        |                 |        |                |        |               |        |                |        |               |        |
| B.C. Hydro              | Ashcroft      | Hat Creek           | 61 800          | 6      | <1.0            | -      | 9.18           | 13     | 235           | 33     | <1.0           | -      | 22.4          | 9      |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | 29 600          | 6      | <0.7            | -      | 13.0           | 15     | 129           | 51     | <0.4           | -      | 15.17         | 13     |
| Tulameen                | Tulameen      | Tulameen            | 11 700          | 6      | <0.6            | -      | <0.7           | -      | 97.4          | 46     | 263.0          | 6      | 19.62         | 10     |
| B.P. Canada             | Chetwynd      | Sukunka             | 15 700          | 6      | 0.85            | 36     | 1.66           | 18     | 1 160         | 16     | 3.73           | 25     | 10.4          | 15     |
| Denison Coal            | E. Kootenay   | Denison             | 8 600           | 7      | <0.4            | -      | 8.60           | 11     | <60           | -      | 12.6           | 12     | 10.68         | 13     |
| Byron Creek             | E. Kootenay   | Byron Creek         | 14 000          | 6      | <1.0            | -      | 0.58           | 52     | 674           | 21     | <1.0           | -      | 10.9          | 15     |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | 17 000          | 6      | 0.67            | 46     | 0.4            | -      | 386           | 16     | 40.7           | 8      | 12.87         | 13     |
| Kaiser Resources        | E. Kootenay   | Elk View            | 18 900          | 6      | <0.5            | -      | <0.2           | -      | <200          | -      | 1.26           | 30     | 8.01          | 14     |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 15 900          | 6      | <0.5            | -      | <0.3           | -      | <200          | -      | 1.02           | 32     | 8.39          | 14     |
| Fording Coal            | E. Kootenay   | Fording             | 15 400          | 6      | 1.34            | 32     | <0.4           | -      | <200          | -      | <0.9           | -      | 11.1          | 14     |

\* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company              | Field       | Mine          | Chlorine<br>ppm | % Err. | Chromium<br>ppm | % Err. | Cobalt<br>ppm | % Err. | Europium<br>ppm | % Err. | Gadolinium<br>ppm | % Err. | Hafnium<br>ppm | % Err. |
|----------------------|-------------|---------------|-----------------|--------|-----------------|--------|---------------|--------|-----------------|--------|-------------------|--------|----------------|--------|
| <b>NOVA SCOTIA</b>   |             |               |                 |        |                 |        |               |        |                 |        |                   |        |                |        |
| River Herbert        | Joggins     | River Herbert | 2 382           | 16     | 33.6            | 11     | 5.67          | 13     | 0.52            | 18     | <30               | -      | 1.00           | 30     |
| Thorburn             | Pictou      | Acadia        | 1 290           | 13     | 45.1            | 10     | 5.37          | 13     | 0.33            | 32     | <90               | -      | 0.91           | 46     |
| Devco                | Sydney      | Lingan        | 1 450           | 11     | 5.09            | 37     | 2.00          | 18     | <0.1            | -      | <50               | -      | <0.2           | -      |
| Devco                | Sydney      | No. 26        | 859             | 12     | <3.0            | -      | 2.74          | 16     | <0.1            | -      | <40               | -      | <0.2           | -      |
| Devco                | Sydney      | Prince        | 789             | 35     | 16.8            | 17     | 6.80          | 12     | 0.46            | 29     | <20               | -      | 0.41           | 52     |
| <b>NEW BRUNSWICK</b> |             |               |                 |        |                 |        |               |        |                 |        |                   |        |                |        |
| N.B. Electric Power  | Minto       | Minto         | 202             | 41     | 12.15           | 20     | 3.81          | 18     | <0.1            | -      | 52.72             | 83     | 0.96           | 28     |
| N.B. Coal            | Minto       | Minto         | 200             | -      | 6.84            | 38     | 10.6          | 11     | <0.2            | -      | <90               | -      | 1.11           | 24     |
| <b>SASKATCHEWAN</b>  |             |               |                 |        |                 |        |               |        |                 |        |                   |        |                |        |
| Manitoba Power       | Estevan     | Estevan       | < 200           | -      | <4.0            | -      | 1.56          | 24     | <0.5            | -      | <20               | -      | 1.05           | 18     |
| M&S Coal             | Estevan     | Bierfait      | < 100           | -      | <4.0            | -      | <0.4          | -      | <0.1            | -      | <50               | -      | 1.37           | 23     |
| M&S Coal             | Estevan     | Boundary Dam  | < 200           | -      | <4.0            | -      | 1.72          | 21     | <0.1            | -      | <60               | -      | 1.43           | 25     |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | < 200           | -      | 16.2            | 18     | 5.59          | 13     | <0.8            | -      | <20               | -      | 1.03           | 22     |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | < 200           | -      | 4.0             | -      | 0.86          | 39     | 0.19            | 100    | <20               | -      | 0.66           | 27     |
| Manalta              | Estevan     | Klimax        | < 200           | -      | <4.0            | -      | 0.47          | 59     | <0.6            | -      | <20               | -      | 1.01           | 23     |
| Poplar River         | Core Sample | Exploratory   | < 500           | -      | <5.0            | -      | 1.16          | 30     | <0.3            | -      | <40               | -      | 1.21           | 21     |
| Poplar River         | Core Sample | Exploratory   | < 200           | -      | <4.0            | -      | 0.48          | 59     | <0.3            | -      | <40               | -      | 1.39           | 20     |

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company                 | Field         | Mine                | Chlorine<br>ppm | % Err. | Chromium<br>ppm | % Err. | Cobalt<br>ppm | % Err. | Europium<br>ppm | % Err. | Gadolinium<br>ppm | % Err. | Hafnium<br>ppm | % Err. |
|-------------------------|---------------|---------------------|-----------------|--------|-----------------|--------|---------------|--------|-----------------|--------|-------------------|--------|----------------|--------|
| <b>ALBERTA</b>          |               |                     |                 |        |                 |        |               |        |                 |        |                   |        |                |        |
| Manalta                 | Sheerness     | Roselyn             | <200            | -      | < 3.0           | -      | 0.84          | 36     | < 0.1           | -      | < 70              | -      | 0.91           | 30     |
| McIntyre                | Grande Cache  | McIntyre            | 434             | 20     | < 3.0           | -      | 2.03          | 20     | < 0.1           | -      | < 40              | -      | 1.43           | 20     |
| McIntyre                | Grande Cache  | McIntyre            | 355             | 50     | < 5.0           | -      | 1.53          | 23     | 0.18            | 60     | < 30              | -      | 1.19           | 18     |
| Luscar Coal             | Castor        | Diplomat            | <100            | -      | < 3.0           | -      | 0.69          | 36     | < 0.3           | -      | < 20              | -      | 0.59           | 22     |
| Manalta                 | Castor        | Vesta               | <200            | -      | < 3.0           | -      | 0.52          | 46     | < 0.3           | -      | < 20              | -      | 1.01           | 19     |
| Century Coals           | Drumheller    | Atlas               | <200            | -      | < 3.0           | -      | 0.42          | 51     | < 0.5           | -      | < 20              | -      | 0.62           | 36     |
| Manalta                 | Pembina       | Highvale            | <400            | -      | < 3.0           | -      | 1.39          | 27     | < 0.4           | -      | < 30              | -      | 0.99           | 25     |
| Manalta                 | Pembina       | Whitewood           | <300            | -      | 2.29            | 60     | 1.43          | 23     | 0.20            | 47     | < 20              | -      | 1.07           | 21     |
| Sundance Mines          | Edmonton      | Sundance            | <300            | -      | 3.01            | 45     | 2.19          | 21     | < 0.5           | -      | < 30              | -      | 0.84           | 24     |
| Imperial Oil            | Edmonton      | Judy Creek          | <200            | -      | < 5.0           | -      | 2.41          | 20     | 0.40            | 47     | < 40              | -      | 1.46           | 22     |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | <200            | -      | 9.21            | 24     | 2.27          | 20     | < 0.2           | -      | < 50              | -      | 1.95           | 18     |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | <400            | -      | < 7.0           | -      | 1.73          | 26     | 0.46            | 23     | < 30              | -      | 1.95           | 15     |
| Cardinal River          | Mountain Park | Cardinal River      | <300            | -      | 5.65            | 26     | 0.78          | 42     | < 0.4           | -      | < 20              | -      | 0.89           | 22     |
| <b>BRITISH COLUMBIA</b> |               |                     |                 |        |                 |        |               |        |                 |        |                   |        |                |        |
| B.C. Hydro              | Ashcroft      | Hat Creek           | < 0.3           | -      | 37.3            | 12     | 9.85          | 11     | < 0.2           | -      | <100              | -      | 1.12           | 48     |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | <100            | -      | 30.5            | 11     | 8.56          | 11     | < 0.2           | -      | < 70              | -      | 3.15           | 20     |
| Tulameen                | Tulameen      | Tulameen            | <100            | -      | 28.4            | 11     | 3.98          | 15     | < 0.1           | -      | < 60              | -      | 1.36           | 24     |
| B.P. Canada             | Chetwynd      | Sukunka             | 497             | 40     | 22.8            | 14     | 2.22          | 22     | 0.15            | 40     | < 40              | -      | 1.00           | 26     |
| Denison Coal            | E. Kootenay   | Denison             | < 90            | -      | 9.59            | 20     | 2.57          | 15     | < 0.1           | -      | < 40              | -      | 1.62           | 22     |
| Byron Creek             | E. Kootenay   | Byron Creek         | <200            | -      | < 5.0           | -      | 0.65          | 47     | 0.46            | 41     | < 30              | -      | 1.46           | 22     |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | <200            | -      | 6.67            | 29     | 1.77          | 20     | < 0.1           | -      | < 50              | -      | 1.16           | 26     |
| Kaiser Resources        | E. Kootenay   | Elk View            | <400            | -      | 4.06            | 37     | 1.49          | 12     | 0.98            | 62     | < 30              | -      | 1.17           | 19     |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 418             | 37     | 2.56            | 55     | 0.96          | 31     | 0.20            | 38     | < 30              | -      | 0.71           | 30     |
| Fording Coal            | E. Kootenay   | Fording             | <400            | -      | 13.0            | 20     | 2.18          | 20     | 0.34            | 30     | < 30              | -      | 1.32           | 19     |

\* Clean coal samples



TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company              | Field       | Mine          | Iodine<br>ppm | % Err. | Iron<br>ppm | % Err. | Lanthanum<br>ppm | % Err. | Magnesium<br>ppm | % Err. | Manganese<br>ppm | % Err. | Potassium<br>ppm | % Err. |
|----------------------|-------------|---------------|---------------|--------|-------------|--------|------------------|--------|------------------|--------|------------------|--------|------------------|--------|
| <b>NOVA SCOTIA</b>   |             |               |               |        |             |        |                  |        |                  |        |                  |        |                  |        |
| River Herbert        | Joggins     | River Herbert | <20           | -      | 37 900      | 7      | 11.1             | 21     | 6 210            | 50     | 219              | 25     | 10 900           | 6      |
| Thorburn             | Pictou      | Acadia        | <20           | -      | 13 000      | 8      | 11.5             | 19     | 1 660            | 75     | 132              | 25     | 7 350            | 10     |
| Devco                | Sydney      | Lingan        | <10           | -      | 8 130       | 9      | 2.28             | 55     | 519              | 75     | 96.9             | 25     | 360              | 39     |
| Devco                | Sydney      | No. 26        | <10           | -      | 5 180       | 10     | 2.40             | 44     | < 100            | -      | 58.5             | 25     | < 100            | -      |
| Devco                | Sydney      | Prince        | <30           | -      | 29 200      | 7      | 12.3             | 20     | <1 000           | -      | 51.3             | 25     | 3 150            | 10     |
| <b>NEW BRUNSWICK</b> |             |               |               |        |             |        |                  |        |                  |        |                  |        |                  |        |
| N.B. Electric Power  | Minto       | Minto         | <20           | -      | 47 300      | 6      | 7.25             | 27     | 333              | 75     | 378              | 10     | < 100            | -      |
| N.B. Coal            | Minto       | Minto         | <20           | -      | 77 100      | 6      | 5.04             | 45     | 175              | 75     | 526              | 25     | < 200            | -      |
| <b>SASKATCHEWAN</b>  |             |               |               |        |             |        |                  |        |                  |        |                  |        |                  |        |
| Manitoba Power       | Estevan     | Estevan       | <20           | -      | 2 950       | 13     | 5.14             | 25     | 1 826            | 75     | 47.5             | 25     | 627              | 28     |
| M&S Coal             | Estevan     | Bienfait      | <10           | -      | 3 090       | 12     | 6.53             | 20     | 1 170            | 75     | 24.3             | 25     | < 200            | -      |
| M&S Coal             | Estevan     | Boundary Dam  | <10           | -      | 3 380       | 11     | 7.86             | 18     | 1 730            | 75     | 26.3             | 25     | < 200            | -      |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | <20           | -      | 3 990       | 12     | 19.1             | 14     | 2 870            | 60     | 34.9             | 25     | 1 770            | 25     |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | <20           | -      | 3 890       | 11     | 3.10             | 36     | 2 400            | 60     | 106              | 25     | 822              | 18     |
| Manalta              | Estevan     | Klimax        | <22           | -      | 3 610       | 12     | 7.28             | 19     | 3 720            | 50     | 48.2             | 25     | < 700            | -      |
| Poplar River         | Core Sample | Exploratory   | <30           | -      | 5 530       | 15     | 5.61             | 25     | 5 590            | 50     | 125              | 25     | 3 280            | 10     |
| Poplar River         | Core Sample | Exploratory   | <30           | -      | 4 700       | 11     | 6.05             | 22     | 4 410            | 50     | 127              | 25     | 2 370            | 13     |

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company                 | Field         | Mine                | Iodine<br>ppm | % Err. | Iron<br>ppm | % Err. | Lanthanum<br>ppm | % Err. | Magnesium<br>ppm | % Err. | Manganese<br>ppm | % Err. | Potassium<br>ppm | % Err. |
|-------------------------|---------------|---------------------|---------------|--------|-------------|--------|------------------|--------|------------------|--------|------------------|--------|------------------|--------|
| <b>ALBERTA</b>          |               |                     |               |        |             |        |                  |        |                  |        |                  |        |                  |        |
| Manalta                 | Sheerness     | Roselyn             | <20           | -      | 4 740       | 12     | 4.64             | 24     | 1 270            | 75     | 113.0            | 25     | < 100            | -      |
| McIntyre                | Grande Cache  | McIntyre            | 10.6          | 50     | 2 070       | 14     | 7.49             | 20     | 614              | 75     | 10.0             | 25     | 786              | 73     |
| McIntyre                | Grande Cache  | McIntyre            | <20           | -      | 2 520       | 13     | 8.17             | 21     | 1 330            | 75     | 11.5             | 25     | 554              | 29     |
| Luscar Coal             | Castor        | Diplomat            | <20           | -      | 2 700       | 12     | 1.45             | 65     | 1 690            | 75     | 26.9             | 25     | 585              | 20     |
| Manalta                 | Castor        | Vesta               | <20           | -      | 2 520       | 12     | 5.06             | 23     | <1 000           | -      | 36.2             | 25     | 1 040            | 18     |
| Century Coals           | Drumheller    | Atlas               | <20           | -      | 3 690       | 11     | 4.79             | 23     | 537              | 75     | 76.5             | 25     | 1 030            | 34     |
| Manalta                 | Pembina       | Highvale            | <30           | -      | 2 760       | 13     | 8.10             | 18     | 1 250            | 75     | 56.8             | 25     | 352              | 52     |
| Manalta                 | Pembina       | Whitewood           | <20           | -      | 4 570       | 11     | 9.56             | 17     | 1 470            | 75     | 144.0            | 25     | 719              | 19     |
| Sundance Mines          | Edmonton      | Sundance            | <30           | -      | 5 070       | 10     | 12.9             | 15     | 3 050            | 50     | 82.5             | 25     | 360              | 63     |
| Imperial Oil            | Edmonton      | Judy Creek          | <30           | -      | 4 350       | 11     | 15.28            | 14     | 903              | 75     | 141.0            | 25     | 1 460            | 18     |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | <10           | -      | 1 850       | 17     | 8.45             | 22     | 692              | 75     | 21.7             | 25     | < 200            | -      |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | <30           | -      | 2 140       | 16     | 10.7             | 22     | 2 300            | 60     | 20.1             | 25     | 584              | 18     |
| Cardinal River          | Mountain Park | Cardinal River      | <20           | -      | 283         | 15     | 5.75             | 24     | 2 416            | 60     | 15.1             | 25     | 489              | 33     |
| <b>BRITISH COLUMBIA</b> |               |                     |               |        |             |        |                  |        |                  |        |                  |        |                  |        |
| B.C. Hydro              | Ashcroft      | Hat Creek           | <10           | -      | 16 400      | 8      | 3.52             | 88     | 3 280            | 50     | 172.0            | 25     | 3 060            | 44     |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | <10           | -      | 9 810       | 9      | < 4.0            | -      | 1 560            | 75     | 41.2             | 25     | < 100            | -      |
| Tulameen                | Tulameen      | Tulameen            | <10           | -      | 9 610       | 8      | 11.8             | 16     | 242              | 75     | 53.5             | 25     | 1 750            | 45     |
| B.P. Canada             | Chetwynd      | Sukunka             | <30           | -      | 3 610       | 14     | 6.59             | 23     | 1 040            | 75     | 18.4             | 25     | 3 370            | 8      |
| Denison Coal            | E. Kootenay   | Denison             | <10           | -      | 3 550       | 11     | 7.83             | 19     | <1 000           | -      | 10.7             | 25     | < 200            | -      |
| Byron Creek             | E. Kootenay   | Byron Creek         | <30           | -      | 2 380       | 16     | < 4.0            | -      | 4 860            | 50     | 32.7             | 25     | 612              | 29     |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | <10           | -      | 3 610       | 12     | < 4.0            | -      | 100              | 75     | 19.5             | 25     | < 100            | -      |
| Kaiser Resources        | E. Kootenay   | Elk View            | <20           | -      | 540         | 34     | 11.3             | 20     | 585              | 75     | 13.4             | 25     | 1 160            | 12     |
| Kaiser Resources        | E. Kootenay   | Elk View*           | <20           | -      | 1 490       | 18     | < 3.0            | -      | 515              | 75     | 20.8             | 25     | 460              | 19     |
| Fording Coal            | E. Kootenay   | Fording             | <30           | -      | 2 060       | 17     | 8.37             | 22     | <1 000           | -      | 23.5             | 25     | 1 165            | 13     |

\* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company           | Field       | Mine          | Samarium<br>ppm | % Err. | Scandium<br>ppm | % Err. | Selenium<br>ppm | % Err. | Sodium<br>ppm | % Err. | Strontium<br>ppm | % Err. | Tantalum<br>ppm | % Err. |
|-------------------|-------------|---------------|-----------------|--------|-----------------|--------|-----------------|--------|---------------|--------|------------------|--------|-----------------|--------|
| NOVA SCOTIA       |             |               |                 |        |                 |        |                 |        |               |        |                  |        |                 |        |
| River Herbert     | Joggins     | River Herbert | 2.65            | 8      | 0.1             | -      | < 5.0           | -      | 1 390         | 6      | <500             | -      | < 0.9           | -      |
| Thorburn          | Pictou      | Acadia        | 2.04            | 9      | 5.75            | 6      | < 5.0           | -      | 517           | 6      | <100             | -      | < 1.0           | -      |
| Devco             | Sydney      | Lingan        | 0.31            | 11     | 0.52            | 30     | < 3.0           | -      | 143           | 8      | < 70             | -      | < 0.4           | -      |
| Devco             | Sydney      | No. 26        | 0.41            | 22     | 0.58            | 10     | < 3.0           | -      | 45.0          | 10     | < 70             | -      | < 0.6           | -      |
| Devco             | Sydney      | Prince        | 1.60            | 10     | 3.18            | 7      | 3.46            | 68     | 355           | 6      | 174              | 50     | < 1.0           | -      |
| NEW BRUNSWICK     |             |               |                 |        |                 |        |                 |        |               |        |                  |        |                 |        |
| N.B. Electric     | Minto       | Minto         | 2.34            | 8      | 2.00            | 8      | 4.89            | 50     | 389           | 19     | <100             | -      | < 1.0           | -      |
| N.B. Coal         | Minto       | Minto         | 2.29            | 9      | 10.5            | 8      | 10.9            | 26     | 192           | 19     | <100             | -      | < 1.0           | -      |
| SASKATCHEWAN      |             |               |                 |        |                 |        |                 |        |               |        |                  |        |                 |        |
| Manitoba Power    | Estevan     | Estevan       | 0.10            | 98     | 1.44            | 8      | < 4.0           | -      | 4 090         | 6      | 414              | 50     | < 0.7           | -      |
| M&S Coal Co.      | Estevan     | Bienfait      | 0.75            | 14     | 1.48            | 7      | < 4.0           | -      | 6 820         | 7      | 170              | 32     | < 0.5           | -      |
| M&S Coal Co.      | Estevan     | Boundary Dam  | 1.09            | 11     | 1.65            | 7      | < 3.0           | -      | 6 740         | 7      | 162              | 33     | < 0.7           | -      |
| Sask. Power Corp. | Estevan     | Boundary Dam  | 3.46            | 8      | 4.34            | 7      | < 4.0           | -      | 7 560         | 6      | 240              | 74     | < 0.9           | -      |
| Sask. Power Corp. | Estevan     | Queen Eliz.   | 0.09            | 100    | 1.16            | 8      | < 3.0           | -      | 1 820         | 6      | <400             | -      | 0.30            | 69     |
| Manalta           | Estevan     | Klimax        | 0.82            | 13     | 1.33            | 8      | < 3.0           | -      | 4 660         | 6      | 681              | 33     | < 0.6           | -      |
| Poplar River      | Core Sample | Exploratory   | 0.06            | 100    | 1.53            | 8      | < 3.0           | -      | 1 090         | 6      | <600             | -      | 0.14            | 100    |
| Poplar River      | Core Sample | Exploratory   | 0.06            | 100    | 1.37            | 8      | < 3.0           | -      | 994           | 6      | <600             | -      | < 0.6           | -      |



TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company                 | Field         | Mine                | Samarium<br>ppm<br>% Err. | Scandium<br>ppm<br>% Err. | Selenium<br>ppm<br>% Err. | Sodium<br>ppm<br>% Err. | Strontium<br>ppm<br>% Err. | Tantalum<br>ppm<br>% Err. |
|-------------------------|---------------|---------------------|---------------------------|---------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| <b>ALBERTA</b>          |               |                     |                           |                           |                           |                         |                            |                           |
| Manalta                 | Sheerness     | Roselyn             | 0.78 12                   | 1.49 8                    | <3.0                      | 1 150 8                 | <100                       | <0.7                      |
| McIntyre                | Grande Cache  | McIntyre            | 0.18 100                  | 2.32 7                    | <3.0                      | 570 8                   | 88.9 46                    | <0.9                      |
| McIntyre                | Grande Cache  | McIntyre            | 1.67 21                   | 2.88 7                    | <3.0                      | 9 150 6                 | <500                       | <0.6                      |
| Luscar Coal             | Castor        | Diplomat            | 1.21 13                   | 0.92 8                    | <3.0                      | 1 370 6                 | 217 74                     | <0.3                      |
| Manalta                 | Castor        | Vesta               | 0.67 15                   | 0.95 9                    | <3.0                      | 3 150 6                 | 230 68                     | <0.5                      |
| Century Coals           | Drumheller    | Atlas               | 1.03 11                   | 1.09 8                    | <3.0                      | 3 830 6                 | 374 51                     | <0.5                      |
| Manalta                 | Pembina       | Highvale            | 0.18 57                   | 1.51 8                    | <2.0                      | 2 470 6                 | <500                       | <1.0                      |
| Manalta                 | Pembina       | Whitewood           | 1.11 11                   | 1.67 8                    | <3.0                      | 228 7                   | <400                       | <1.0                      |
| Sundance Mines          | Edmonton      | Sundance            | 2.00 9                    | 1.96 7                    | <3.0                      | 3 180 6                 | <500                       | <0.8                      |
| Imperial Oil            | Edmonton      | Judy Creek          | 3.02 8                    | 3.20 7                    | <3.0                      | 1 910 6                 | <600                       | <0.7                      |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | 1.40 11                   | 4.80 6                    | <4.0                      | 300 14                  | 170 26                     | <0.6                      |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | 2.19 11                   | 6.21 6                    | <4.0                      | 241 6                   | <500                       | <0.8                      |
| Cardinal River          | Mountain Park | Cardinal River      | 0.87 17                   | 2.04 7                    | <4.0                      | 1 000 6                 | <400                       | <0.7                      |
| <b>BRITISH COLUMBIA</b> |               |                     |                           |                           |                           |                         |                            |                           |
| B.C. Hydro              | Ashcroft      | Hat Creek           | 2.48 9                    | 11.6 6                    | <5.0                      | 680 8                   | <200                       | <1.0                      |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | 90.1 10                   | 7.81 6                    | <5.0                      | 787 9                   | <90                        | <0.8                      |
| Tulameen                | Tulameen      | Tulameen            | 1.76 9                    | 2.65 7                    | <4.0                      | 165 11                  | <90                        | <0.9                      |
| B.P. Canada             | Chetwynd      | Sukunka             | 0.17 63                   | 2.58 7                    | 2.49 71                   | 786 6                   | <600                       | <0.9                      |
| Denison Coal            | E. Kootenay   | Denison             | 0.88 13                   | 2.24 11                   | <3.0                      | 448 8                   | 65.5 57                    | <0.4                      |
| Byron Creek             | E. Kootenay   | Byron Creek         | 0.10 100                  | 4.42 7                    | <4.0                      | 810 6                   | <600                       | <0.7                      |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | 1.23 11                   | 3.56 7                    | <4.0                      | 84.7 14                 | <70                        | <0.5                      |
| Kaiser Resources        | E. Kootenay   | Elk View            | 0.06 100                  | 3.27 6                    | <3.0                      | 42.8 9                  | <500                       | <0.4                      |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 1.00 12                   | 3.80 7                    | <3.0                      | 44.8 8                  | <500                       | <0.4                      |
| Fording Coal            | E. Kootenay   | Fording             | 1.41 11                   | 3.94 7                    | <4.0                      | 57.8 9                  | <500                       | <0.7                      |

\* Clean coal samples

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company              | Field       | Mine          | Terbium<br>ppm | % Err. | Thorium<br>ppm | % Err. | Titanium<br>ppm | % Err. | Uranium<br>ppm | % Err. | Vanadium<br>ppm | % Err. | Ytterbium<br>ppm | % Err. |
|----------------------|-------------|---------------|----------------|--------|----------------|--------|-----------------|--------|----------------|--------|-----------------|--------|------------------|--------|
| <b>NOVA SCOTIA</b>   |             |               |                |        |                |        |                 |        |                |        |                 |        |                  |        |
| River Herbert        | Joggins     | River Herbert | <0.9           | -      | 2.95           | 11     | 1 160           | 16     | 1.78           | 10     | 49.1            | 8      | 0.99             | 32     |
| Thorburn             | Pictou      | Acadia        | <1.0           | -      | 3.62           | 9      | 2 920           | 16     | 1.24           | 10     | 58.0            | 10     | 0.89             | 34     |
| Devco                | Sydney      | Lingan        | <0.4           | -      | 0.30           | 42     | < 400           | -      | 0.20           | 10     | 3.88            | 39     | <0.2             | -      |
| Devco                | Sydney      | No. 26        | <0.4           | -      | 0.20           | 53     | 340             | 53     | <0.1           | -      | 5.34            | 21     | <0.3             | -      |
| Devco                | Sydney      | Prince        | <1.0           | -      | 2.03           | 15     | 644             | 23     | 0.96           | 10     | 9.13            | 37     | 0.86             | 35     |
| <b>NEW BRUNSWICK</b> |             |               |                |        |                |        |                 |        |                |        |                 |        |                  |        |
| N.B. Electric Power  | Minto       | Minto         | <0.8           | -      | 1.16           | 20     | 1 670           | 26     | 1.18           | 10     | 26.98           | 12     | 0.94             | 33     |
| N.B. Coal            | Minto       | Minto         | <0.9           | -      | 1.10           | 24     | 1 270           | 37     | 1.55           | 10     | 31.6            | 12     | 0.98             | 34     |
| <b>SASKATCHEWAN</b>  |             |               |                |        |                |        |                 |        |                |        |                 |        |                  |        |
| Manitoba Power       | Estevan     | Estevan       | <0.5           | -      | 2.14           | 14     | 508             | 24     | 1.48           | 10     | 7.56            | 18     | <0.4             | -      |
| M&S Coal             | Estevan     | Bienfait      | <0.4           | -      | 3.23           | 11     | 1 730           | 20     | 2.91           | 10     | 5.01            | 35     | <0.3             | -      |
| M&S Coal Co.         | Estevan     | Boundary Dam  | <0.5           | -      | 2.70           | 12     | 1 650           | 21     | 1.77           | 10     | 7.93            | 23     | 0.62             | 32     |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | <0.8           | -      | 1.99           | 15     | 421             | 24     | 2.55           | 10     | 22.4            | 10     | 1.93             | 20     |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | <0.5           | -      | 1.85           | 14     | 162             | 53     | 0.78           | 10     | 4.65            | 26     | 0.28             | 56     |
| Manalta              | Estevan     | Klimax        | <0.5           | -      | 3.68           | 10     | 626             | 21     | 1.79           | 10     | 4.74            | 28     | 0.21             | 90     |
| Poplar River         | Core Sample | Exploratory   | <0.3           | -      | 3.36           | 11     | 681             | 22     | 2.35           | 10     | 17.2            | 14     | 0.26             | 71     |
| Poplar River         | Core Sample | Exploratory   | <0.6           | -      | 3.92           | 10     | 678             | 23     | 2.12           | 10     | 17.5            | 13     | <0.3             | -      |

TABLE 3 CONCENTRATION OF TRACE ELEMENTS IN COAL SAMPLES AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS (cont'd.)

| Company                 | Field         | Mine                | Terbium |        | Thorium |        | Titanium |        | Uranium |        | Vanadium |        | Ytterbium |        |
|-------------------------|---------------|---------------------|---------|--------|---------|--------|----------|--------|---------|--------|----------|--------|-----------|--------|
|                         |               |                     | ppm     | % Err. | ppm     | % Err. | ppm      | % Err. | ppm     | % Err. | ppm      | % Err. | ppm       | % Err. |
| <b>ALBERTA</b>          |               |                     |         |        |         |        |          |        |         |        |          |        |           |        |
| Manalta                 | Sheerness     | Roselyn             | <0.4    | -      | 1.82    | 14     | 500      | -      | 1.11    | 10     | 4.72     | 32     | 0.36      | 42     |
| McIntyre                | Grande Cache  | McIntyre            | <0.5    | -      | 1.51    | 18     | 1 550    | 17     | 1.72    | 10     | 26.3     | 11     | 0.71      | 35     |
| McIntyre                | Grande Cache  | McIntyre            | <0.6    | -      | 1.55    | 18     | 654      | 19     | 1.55    | 10     | 26.9     | 9      | 0.96      | 27     |
| Luscar Coal             | Castor        | Diplomat            | <0.3    | -      | 1.48    | 15     | 220      | 34     | 0.49    | 10     | 2.83     | 31     | <0.3      | -      |
| Manalta                 | Castor        | Vesta               | <0.5    | -      | 2.11    | 12     | 161      | 48     | 0.87    | 10     | 0.94     | 78     | 0.36      | 49     |
| Century Coals           | Drumheller    | Atlas               | <0.4    | -      | 2.88    | 10     | 213      | 41     | 1.09    | 10     | 2.11     | 46     | 0.87      | 23     |
| Manalta                 | Pembina       | Highvale            | <0.5    | -      | 2.96    | 10     | 451      | 27     | 1.73    | 10     | 4.09     | 31     | 0.70      | 31     |
| Manalta                 | Pembina       | Whitewood           | <0.5    | -      | 2.72    | 11     | 556      | 23     | 1.45    | 10     | 9.47     | 17     | 0.56      | 38     |
| Sundance Mines          | Edmonton      | Sundance            | <0.5    | -      | 2.55    | 10     | 403      | 28     | 1.47    | 10     | 9.29     | 17     | 1.43      | 18     |
| Imperial Oil            | Edmonton      | Judy Creek          | <0.6    | -      | 6.17    | 9      | 942      | 17     | 1.55    | 10     | 10.62    | 16     | 1.31      | 22     |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | <0.7    | -      | 2.93    | 12     | 2 520    | 14     | 2.02    | 10     | 33.8     | 11     | 1.09      | 31     |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | <0.9    | -      | 4.82    | 10     | 989      | 15     | 1.95    | 10     | 62.9     | 7      | 1.19      | 31     |
| Cardinal River          | Mountain Park | Cardinal River      | <0.6    | -      | 2.22    | 11     | 420      | 23     | 1.15    | 10     | 11.8     | 12     | 0.13      | 100    |
| <b>BRITISH COLUMBIA</b> |               |                     |         |        |         |        |          |        |         |        |          |        |           |        |
| B.C. Hydro              | Ashcroft      | Hat Creek           | <1.0    | -      | 2.54    | 14     | 5.5      | 12     | 1.89    | 10     | 93.5     | 8      | 1.90      | 20     |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | <1.0    | -      | 1.45    | 16     | 3 010    | 16     | 1.19    | 10     | 108.0    | 8      | 1.37      | 27     |
| Tulameen                | Tulameen      | Tulameen            | <0.7    | -      | 2.19    | 13     | 1 600    | 21     | 1.49    | 10     | 34.3     | 10     | 1.04      | 27     |
| B.P. Canada             | Chetwynd      | Sukunka             | <0.6    | -      | 1.79    | 15     | 688      | 22     | 1.49    | 10     | 68.8     | 8      | 0.30      | 69     |
| Denison Coal            | E. Kootenay   | Denison             | <0.5    | -      | 1.56    | 14     | 983      | 25     | 1.57    | 10     | 23.4     | 12     | 0.32      | 40     |
| Byron Creek             | E. Kootenay   | Byron Creek         | <0.9    | -      | 1.26    | 23     | 1 110    | 15     | 0.97    | 10     | 18.6     | 12     | 0.66      | 50     |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | <0.7    | -      | 1.62    | 16     | 2 520    | 13     | 1.22    | 10     | 46.4     | 9      | 0.95      | 28     |
| Kaiser Resources        | E. Kootenay   | Elk View            | <0.5    | -      | 1.35    | 15     | 945      | 15     | 0.95    | 10     | 23.8     | 10     | 0.42      | 49     |
| Kaiser Resources        | E. Kootenay   | Elk View*           | <0.6    | -      | 1.45    | 15     | 733      | 19     | 0.62    | 10     | 19.4     | 11     | 0.69      | 32     |
| Fording Coal            | E. Kootenay   | Fording             | <0.7    | -      | 1.97    | 15     | 1 040    | 15     | 1.23    | 10     | 39.4     | 9      | 1.17      | 27     |

\* Clean coal samples



TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY

| Company              | Field       | Mine          | Aluminum | Barium | Beryllium | Boron | Cadmium | Calcium | Chromium | Cobalt |
|----------------------|-------------|---------------|----------|--------|-----------|-------|---------|---------|----------|--------|
| <b>NOVA SCOTIA</b>   |             |               |          |        |           |       |         |         |          |        |
| River Herbert        | Joggins     | River Herbert | 29 950   | 211.2  | 0.9       | -     | -       | 6 488   | 56.4     | 28.2   |
| Thorburn             | Pictou      | Acadia        | 42 760   | 196.7  | 0.9       | 1 872 | -       | 1 929   | 50.0     | 3.8    |
| Devco                | Sydney      | Lingan        | 2 640    | 13.6   | -         | -     | -       | 668.6   | 20.3     | 22.7   |
| Devco                | Sydney      | No. 26        | 1 590    | 15.9   | -         | 149.1 | -       | 188.8   | 4.0      | -      |
| Devco                | Sydney      | Prince        | 18 080   | 93.0   | 1.1       | -     | -       | 904.1   | 41.1     | 31.6   |
| <b>NEW BRUNSWICK</b> |             |               |          |        |           |       |         |         |          |        |
| N.B. Electric Power  | Minto       | Minto         | 9 382    | 43.1   | 1.5       | -     | -       | 5 511   | 25.9     | 26.4   |
| N.B. Coal            | Minto       | Minto         | 9 083    | 33.9   | 1.7       | -     | -       | 10 970  | 20.2     | 32.7   |
| <b>SASKATCHEWAN</b>  |             |               |          |        |           |       |         |         |          |        |
| Manitoba Power       | Estevan     | Estevan       | 11 440   | 841.4  | -         | 850.6 | -       | 13 370  | 7.3      | 5.5    |
| M&S Coal Co.         | Estevan     | Bienfait      | 13 930   | 1 213  | -         | 1 241 | -       | 12 510  | 7.6      | 3.8    |
| M&S Coal Co.         | Estevan     | Boundary Dam  | 16 440   | 1 086  | 0.5       | 1 163 | -       | 14 610  | 9.9      | -      |
|                      |             |               | 16 430   | 1 080  | -         | 1 540 | -       | 12 960  | 9.5      | -      |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | 15 180   | 755.0  | 1.8       | 1 064 | -       | 11 430  | 20.3     | 3.9    |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | 10 150   | 430.8  | -         | 741.0 | -       | 3 542   | 4.0      | -      |
| Manalta              | Estevan     | Klimax        | 14 710   | 253.9  | -         | 1 340 | -       | 16 490  | 6.0      | -      |
| Poplar River         | Core Sample | Exploratory   | 21 640   | 543.0  | -         | 1 858 | 7.7     | 7 240   | 14.8     | -      |
| Poplar River         | Core Sample | Exploratory   | 15 910   | 372.9  | -         | 1 415 | 8.8     | 15 520  | 10.5     | -      |

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company                 | Field         | Mine                | Aluminum | Barium | Beryllium | Boron | Cadmium | Calcium | Chromium | Cobalt |
|-------------------------|---------------|---------------------|----------|--------|-----------|-------|---------|---------|----------|--------|
| <b>ALBERTA</b>          |               |                     |          |        |           |       |         |         |          |        |
| Manalta                 | Sheerness     | Roselyn             | 17 760   | 278.6  | -         | 912.3 | -       | 11 030  | 5.6      | -      |
| McIntyre                | Grande Cache  | McIntyre            | 11 160   | 328.4  | -         | 469.8 | -       | 1 944   | 8.6      | -      |
| McIntyre                | Grande Cache  | McIntyre            | 11 480   | 400.5  | -         | 427.3 | 7.5     | 1 801   | 10.4     | -      |
| Luscar Coal             | Castor        | Diplomat            | 7 078    | 412.5  | -         | 849.7 | -       | 9 468   | 1.9      | 7.6    |
| Mahalta                 | Castor        | Vesta               | 11 280   | 508.7  | -         | 833.6 | -       | 8 132   | 0.9      | -      |
| Century Coals           | Drumheller    | Atlas               | 13 530   | 568.9  | -         | 1 225 | -       | 7 960   | 3.0      | -      |
| Manalta                 | Pembina       | Highvale            | 20 930   | 589.0  | 0.4       | 1 413 | 7.9     | 12 270  | 4.4      | -      |
| Manalta                 | Pembina       | Whitewood           | 15 590   | 415.0  | -         | 1 057 | 7.0     | 14 100  | 7.3      | -      |
| Sundance Mines          | Edmonton      | Sundance            | 15 420   | 597.5  | 0.6       | 916.9 | -       | 12 760  | 4.8      | -      |
| Imperial Oil            | Edmonton      | Judy Creek          | 29 050   | 528.6  | 1.3       | -     | -       | 12 360  | 16.0     | 16.2   |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | 14 320   | 727.3  | -         | 1 004 | -       | 2 809   | 7.9      | 10.2   |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | 18 660   | 557.9  | 0.5       | 648.4 | -       | 3 825   | 13.0     | -      |
| Cardinal River          | Mountain Park | Cardinal River      | 11 450   | 473.9  | -         | 652.6 | -       | 4 618   | 6.4      | -      |
| <b>BRITISH COLUMBIA</b> |               |                     |          |        |           |       |         |         |          |        |
| B.C. Hydro              | Ashcroft      | Hat Creek           | 77 240   | 343.1  | 0.8       | 2 455 | 6.6     | 7 942   | 62.6     | 14.2   |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | 32 000   | 115.8  | 0.6       | 1 688 | 7.1     | 5 410   | 42.0     | 11.5   |
| Tulameen                | Tulameen      | Tulameen            | 12 480   | 88.5   | 1.0       | -     | -       | 1 200   | 35.8     | 22.1   |
| B.P. Canada             | Chetwynd      | Sukunka             | 14 470   | 925.2  | -         | 827.5 | -       | 3 579   | 22.5     | 2.8    |
| Denison Coal            | E. Kootenay   | Denison             | 8 460    | 697.2  | -         | -     | -       | 2 613   | 18.5     | 12.4   |
| Byron Creek             | E. Kootenay   | Byron Creek         | 25 430   | 702.9  | -         | 1 152 | 8.3     | 6 587   | 8.2      | -      |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | 14 050   | 324.8  | -         | 633.3 | 8.2     | 1 725   | 11.3     | -      |
| Kaiser Resources        | E. Kootenay   | Elk View            | 24 520   | 104.4  | -         | 790.2 | 8.6     | 2 538   | 11.9     | -      |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 13 380   | 77.1   | -         | 544.7 | 8.5     | 1 945   | 8.0      | -      |
| Fording Coal            | E. Kootenay   | Fording             | 14 320   | 71.8   | -         | 963.3 | -       | 992.1   | 11.0     | -      |

\* Clean coal samples

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company              | Field       | Mine          | Copper | Iron   | Lead | Magnesium | Manganese | Molybdenum | Nickel | Phosphorus |
|----------------------|-------------|---------------|--------|--------|------|-----------|-----------|------------|--------|------------|
| <b>NOVA SCOTIA</b>   |             |               |        |        |      |           |           |            |        |            |
| River Herbert        | Joggins     | River Herbert | 23.9   | 30 800 | 52.6 | 2 638     | 208.4     | 178.4      | 25.3   | 591.3      |
| Thorburn             | Pictou      | Acadia        | 16.9   | 15 010 | 11.4 | 1 749     | 102.6     | -          | 26.6   | 209.1      |
| Devco                | Sydney      | Lingan        | 13.6   | 2 373  | 10.9 | 216.8     | 102.5     | 145.2      | 8.2    | -          |
| Devco                | Sydney      | No. 26        | 3.6    | 2 909  | 1.8  | 66.2      | 33.6      | -          | 4.5    | -          |
| Devco                | Sydney      | Prince        | 19.5   | 29 320 | 52.7 | 630.3     | 49.2      | 149.2      | 28.1   | 245.8      |
| <b>NEW BRUNSWICK</b> |             |               |        |        |      |           |           |            |        |            |
| N.B. Electric Power  | Minto       | Minto         | 24.4   | 49 190 | 3.6  | 396.2     | 335.2     | 209.5      | 21.9   | 792.5      |
| N.B. Coal            | Minto       | Minto         | 32.3   | 89 960 | 1.9  | 423.4     | 454.2     | 192.4      | 34.6   | 1 116.0    |
| <b>SASKATCHEWAN</b>  |             |               |        |        |      |           |           |            |        |            |
| Manitoba Power       | Estevan     | Estevan       | 10.2   | 1 005  | 12.8 | 2 426     | 33.9      | -          | 7.3    | 164.8      |
| M&S Coal Co.         | Estevan     | Bienfait      | 12.2   | 3 297  | 7.6  | 2 132     | 18.8      | -          | 6.6    | -          |
| M&S Coal Co.         | Estevan     | Boundary Dam  | 14.5   | 3 854  | 11.5 | 2 682     | 19.8      | -          | -      | 86.5       |
|                      |             |               | 13.4   | 3 793  | 9.4  | 2 601     | 17.7      | -          | -      | 65.7       |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | 17.8   | 4 031  | 9.9  | 2 622     | 27.5      | -          | 21.7   | 78.8       |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | 5.6    | 4 442  | 7.7  | 976.5     | 110.1     | -          | 4.8    | 153.2      |
| Manalta              | Estevan     | Klimax        | 8.6    | 4 338  | 5.6  | 2 717     | 38.9      | -          | -      | 224.9      |
| Poplar River         | Core Sample | Exploratory   | 12.4   | 6 598  | 13.4 | 5 124     | 112.0     | -          | 6.7    | -          |
| Poplar river         | Core Sample | Exploratory   | 14.5   | 4 675  | 17.6 | 4 334     | 98.6      | -          | 6.8    | -          |



TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company                 | Field         | Mine                | Copper | Iron   | Lead | Magnesium | Manganese | Molybdenum | Nickel | Phosphorus |
|-------------------------|---------------|---------------------|--------|--------|------|-----------|-----------|------------|--------|------------|
| <b>ALBERTA</b>          |               |                     |        |        |      |           |           |            |        |            |
| Manalta                 | Sheerness     | Roselyn             | 3.6    | 4 347  | 5.6  | 1 440     | 154.2     | -          | -      | 84.1       |
| McIntyre                | Grande Cache  | McIntyre            | 10.1   | 1 879  | 3.7  | 265.1     | 5.0       | -          | 4.7    | 344.2      |
| McIntyre                | Grande Cache  | McIntyre            | 9.8    | 432.6  | 5.0  | 243.8     | 3.8       | -          | 7.5    | 318.4      |
| Luscar Coal             | Castor        | Diplomat            | 5.2    | 2 438  | 3.8  | 813.4     | 25.1      | -          | -      | 333.4      |
| Manalta                 | Castor        | Vesta               | 5.5    | 3 171  | 1.9  | 482.4     | 46.8      | -          | -      | 457.2      |
| Century Coals           | Drumheller    | Atlas               | 9.2    | 3 832  | 4.0  | 746.7     | 102.7     | -          | -      | 632.1      |
| Manalta                 | Pembina       | Highvale            | 4.4    | 3 418  | 7.1  | 834.5     | 97.3      | -          | 6.2    | -          |
| Manalta                 | Pembina       | Whitewood           | 4.8    | 4 996  | 19.4 | 1 542     | -         | -          | 9.7    | -          |
| Sundance Mines          | Edmonton      | Sundance            | 9.5    | 5 250  | 5.5  | 730.5     | 86.8      | -          | -      | 73.4       |
| Imperial Oil            | Edmonton      | Judy Creek          | 9.7    | 4 547  | 10.8 | 1 065     | 151.6     | 99.2       | 9.0    | 90.2       |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | 16.3   | 1 795  | 13.0 | 598.0     | 12.1      | 18.6       | 4.7    | 678.9      |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | 16.2   | 1 913  | 11.2 | 700.7     | 10.4      | -          | 5.6    | 578.5      |
| Cardinal River          | Mountain Park | Cardinal River      | 8.0    | 2 318  | 7.4  | 923.6     | 6.4       | -          | -      | 195.5      |
| <b>BRITISH COLUMBIA</b> |               |                     |        |        |      |           |           |            |        |            |
| B.C. Hydro              | Ashcroft      | Hat Creek           | 61.4   | 20 560 | 3.8  | 3 933     | 177.2     | -          | 50.2   | 75.8       |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | 58.7   | 9 989  | 7.1  | 2 413     | 29.4      | -          | 37.1   | -          |
| Tulameen                | Tulameen      | Tulameen            | 36.0   | 10 460 | 1.9  | 561.4     | 54.3      | 105.6      | 21.1   | 105.6      |
| B.P. Canada             | Chetwynd      | Sukunka             | 8.8    | 3 926  | 5.6  | 1 249     | 7.7       | -          | 13.2   | 197.3      |
| Denison Coal            | E. Kootenay   | Denison             | 29.9   | 4 568  | 5.7  | 1 249     | 7.5       | 76.3       | 13.4   | 295.7      |
| Byron Creek             | E. Kootenay   | Byron Creek         | 12.5   | 2 708  | 5.5  | 1 354     | 15.9      | -          | -      | 304.0      |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | 15.1   | 3 769  | 2.7  | 157.9     | 9.6       | -          | 6.4    | 793.9      |
| Kaiser Resources        | E. Kootenay   | Elk View            | 9.0    | 803.6  | 5.7  | 373.6     | 4.5       | -          | -      | 162.8      |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 9.3    | 1 499  | 7.6  | 10.6      | -         | -          | 341.6  | -          |
| Fording Coal            | E. Kootenay   | Fording             | 11.8   | 2 087  | 3.7  | 262.1     | 16.0      | -          | 7.5    | 308.9      |

\* Clean coal samples

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company              | Field       | Mine          | Potassium | Silver | Sodium | Strontium | Thorium | Titanium | Vanadium | Zinc  | Zirconium |
|----------------------|-------------|---------------|-----------|--------|--------|-----------|---------|----------|----------|-------|-----------|
| <b>NOVA SCOTIA</b>   |             |               |           |        |        |           |         |          |          |       |           |
| River Herbert        | Joggins     | River Herbert | 9 163     | 1.1    | -      | 73.7      | 4.7     | 1 005.0  | 55.4     | 49.8  | 53.6      |
| Thorburn             | Pictou      | Acadia        | 7 156     | -      | 1 806  | 121.6     | 1.9     | 901.8    | 59.7     | 45.6  | 38.8      |
| Devco                | Sydney      | Lingan        | 290.3     | 2.3    | -      | 10.4      | 2.7     | 127.0    | 5.3      | 11.8  | 104.3     |
| Devco                | Sydney      | No. 26        | 72.3      | -      | 361.4  | 4.8       | -       | 77.3     | 3.3      | 5.4   | 2.6       |
| Devco                | Sydney      | Prince        | 3 318     | 1.0    | -      | 130.8     | 6.1     | 677.7    | 28.3     | 47.4  | 33.4      |
| <b>NEW BRUNSWICK</b> |             |               |           |        |        |           |         |          |          |       |           |
| N.B. Electric Power  | Minto       | Minto         | 1 694     | 0.7    | -      | 43.8      | 3.6     | 519.2    | 21.0     | 26.4  | 43.1      |
| N.B. Coal Ltd.       | Minto       | Minto         | 1 068     | 1.9    | -      | 45.9      | 2.9     | 510.0    | 25.8     | 44.3  | 53.3      |
| <b>SASKATCHEWAN</b>  |             |               |           |        |        |           |         |          |          |       |           |
| Manitoba Power       | Estevan     | Estevan       | 805.7     | -      | -      | 380.9     | 6.4     | 564.9    | 9.0      | 54.0  | 33.9      |
| M&S Coal Co.         | Estevan     | Bienfait      | 691.6     | 0.2    | -      | 401.7     | 6.6     | 891.5    | 9.0      | 138.3 | 41.2      |
| M&S Coal Co.         | Estevan     | Boundary Dam  | 797.8     | -      | 7 209  | 456.6     | -       | 747.8    | 10.9     | 89.4  | 52.1      |
|                      |             |               | 732.3     | 1.9    | 7 323  | 456.3     | -       | 745.5    | 10.7     | 9.4   | 334.2     |
| Sask. Power Corp.    | Estevan     | Boundary Dam  | 1 459     | 0.4    | 8 279  | 426.8     | 1.0     | 592.4    | 31.7     | 48.3  | 64.2      |
| Sask. Power Corp.    | Estevan     | Queen Eliz.   | 813.8     | -      | -      | 201.1     | 1.9     | 282.4    | 5.1      | 6.7   | 303.5     |
| Manalta              | Estevan     | Klimax        | 75.0      | -      | 5 435  | 551.9     | 2.8     | 874.3    | 7.5      | 11.2  | 41.4      |
| Poplar River         | Core Sample | Exploratory   | 2 988     | -      | 2 203  | 259.5     | 2.9     | 688.6    | 20.1     | 16.3  | 58.4      |
| Poplar River         | Core Sample | Exploratory   | 1 972     | 0.2    | 1 855  | 217.7     | 2.9     | 528.1    | 15.2     | 22.5  | 48.2      |

TABLE 4 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company                 | Field         | Mine                | Potassium | Silver | Sodium | Strontium | Thorium | Titanium | Vanadium | Zinc  | Zirconium |
|-------------------------|---------------|---------------------|-----------|--------|--------|-----------|---------|----------|----------|-------|-----------|
| <b>ALBERTA</b>          |               |                     |           |        |        |           |         |          |          |       |           |
| Manalta                 | Sheerness     | Roselyn             | 1 440     | -      | 1 776  | 211.3     | 1.9     | 388.9    | 6.3      | 5.6   | 256.1     |
| McIntyre                | Grande Cache  | McIntyre            | 241.9     | -      | 837.2  | 142.3     | -       | 654.9    | 26.9     | 14.9  | 35.1      |
| McIntyre                | Grande Cache  | McIntyre            | 318.4     | -      | 670.2  | 163.4     | -       | 628.4    | 31.1     | 50.3  | 33.8      |
| Luscar Coal             | Castor        | Diplomat            | 743.0     | 2.7    | -      | 254.3     | 6.7     | 194.3    | 3.0      | 10.5  | 24.7      |
| Manalta                 | Castor        | Vesta               | 846.2     | -      | 3 891  | 374.5     | -       | 216.9    | 2.8      | 4.9   | 37.4      |
| Century Coals           | Drumheller    | Atlas               | 1 007     | 0.9    | -      | 355.6     | 5.0     | 288.4    | 4.3      | 110.6 | 47.7      |
| Manalta                 | Pembina       | Highvale            | 362.1     | -      | 3 709  | 145.7     | 3.5     | 538.7    | 6.5      | 15.9  | 64.3      |
| Manalta                 | Pembina       | Whitewood           | 660.9     | -      | 969.2  | 62.0      | 3.5     | 500.5    | 9.1      | 22.9  | 49.0      |
| Sundance Mines          | Edmonton      | Sundance            | 266.2     | -      | 3 212  | 144.1     | 1.8     | 509.4    | 10.5     | 9.2   | 47.4      |
| Imperial Oil            | Edmonton      | Judy Creek          | 775.8     | 0.8    | -      | 133.5     | 9.0     | 1 001    | 15.2     | 14.4  | 117.3     |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | 734.7     | 0.8    | -      | 200.0     | 6.5     | 1 116    | 34.9     | 22.3  | 52.7      |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | 307.9     | -      | 373.2  | 223.9     | -       | 1 316    | 44.4     | 53.2  | 66.6      |
| Cardinal River          | Mountain Park | Cardinal River      | 204.8     | -      | -      | 128.5     | 0.9     | 530.7    | 14.9     | 37.2  | 33.0      |
| <b>BRITISH COLUMBIA</b> |               |                     |           |        |        |           |         |          |          |       |           |
| B.C. Hydro              | Ashcroft      | Hat Creek           | 3 412     | -      | 2 654  | 124.1     | 3.8     | 3 080    | 125.1    | 58.8  | 134.6     |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | 1 538     | 3.1    | 1 945  | 67.6      | -       | 1 768    | 128.2    | 35.4  | 476.4     |
| Tulameen                | Tulameen      | Tulameen            | 2 774     | 1.4    | 0      | 23.1      | 2.9     | 838.8    | 38.9     | 26.9  | 71.2      |
| B.P. Canada             | Chetwynd      | Sukunka             | 3 250     | -      | 1 409  | 119.3     | -       | 741.1    | 66.6     | 29.1  | 21.2      |
| Denison Coal            | E. Kootenay   | Denison             | 419.6     | 3.3    | -      | 100.1     | 1.9     | 477.8    | 24.6     | 17.2  | 36.4      |
| Byron Creek             | E. Kootenay   | Byron Creek         | 359.3     | -      | 1 290  | 234.0     | -       | 1 621    | 29.2     | 10.1  | 59.1      |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | 428.9     | -      | 365.0  | 130.5     | -       | 756.4    | 40.0     | 18.2  | 37.1      |
| Kaiser Resources        | E. Kootenay   | Elk View            | 785.4     | -      | 287.4  | 26.1      | -       | 1 226    | 27.1     | 88.1  | 38.0      |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 161.3     | -      | -      | 22.7      | -       | 780      | 22.8     | 11.4  | 32.9      |
| Fording Coal            | E. Kootenay   | Fording             | 589.7     | -      | -      | 36.2      | -       | 864.8    | 38.8     | 19.7  | 32.9      |

\* Clean coal samples



TABLE 5 CONCENTRATION OF TRACE ELEMENTS (IN PPM) IN COAL SAMPLES AS DETERMINED BY  
ATOMIC ABSORPTION SPECTROMETRY

| Company                 | Field        | Mine                | Copper | Iron   | Lead | Manganese | Zinc |
|-------------------------|--------------|---------------------|--------|--------|------|-----------|------|
| <b>NOVA SCOTIA</b>      |              |                     |        |        |      |           |      |
| Devco                   | Sydney       | No. 26              | 6.7    | 3 250  | 0.9  | 61.8      | 10.5 |
| <b>SASKATCHEWAN</b>     |              |                     |        |        |      |           |      |
| Poplar River            | Core Sample  | Exploratory         | 18.6   | 5 749  | 20.5 | 107.4     | 19.5 |
| <b>ALBERTA</b>          |              |                     |        |        |      |           |      |
| McIntyre                | Grande Cache | McIntyre            | 10.9   | 1 885  | 9.2  | 5.9       | 44.4 |
| Coleman Collieries      | Crowsnest    | Tent Mountain       | 17.7   | 1 987  | 13.9 | 12.1      | 28.9 |
| <b>BRITISH COLUMBIA</b> |              |                     |        |        |      |           |      |
| B.C. Hydro              | Ashcroft     | Hat Creek*          | 68.2   | 21 133 | 19.9 | 183.9     | 56.9 |
| B.C. Hydro              | Ashcroft     | Hat Creek           | 62.8   | 10 784 | 12.4 | 31.8      | 56.9 |
| B.P. Canada             | Chetwynd     | Sukunka             | 9.4    | 4 245  | 8.4  | 8.5       | 28.2 |
| Byron Creek             | E. Kootenay  | Byron Creek         | 13.8   | 2 929  | 11.0 | 19.34     | 10.1 |
| Kaiser Resources        | E. Kootenay  | Kaiser (Seam No. 7) | 15.5   | 3 832  | 6.3  | 11.0      | 15.6 |
| Kaiser Resources        | E. Kootenay  | Elk View*           | 8.62   | 729    | 5.7  | 4.5       | 14.4 |

\* Clean coal samples

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY

| Company             | Field       | Mine          | Aluminum |        | Barium  |   | Chromium    |            | Cobalt    |  | Iron    |        | Magnesium |     |           |
|---------------------|-------------|---------------|----------|--------|---------|---|-------------|------------|-----------|--|---------|--------|-----------|-----|-----------|
|                     |             |               | NAA/PES  |        | NAA/PES |   | NAA/PES     |            | NAA/PES   |  | NAA/PES |        | NAA/PES   |     |           |
| NOVA SCOTIA         |             |               |          |        |         |   |             |            |           |  |         |        |           |     |           |
| River Herbert       | Joggins     | River Herbert | 25       | 300/29 | 950     | < | 200/211.2   | 33.6/56.4  | 5.67/28.2 |  | 37      | 900/30 | 800       | 6   | 210/2 638 |
| Thorburn            | Pictou      | Acadia        | 43       | 400/42 | 760     |   | 259/196.7   | 45.1/50.0  | 5.57/3.8  |  | 13      | 000/15 | 010       | 1   | 660/1 749 |
| Devco               | Sydney      | Lingan        | 1        | 940/2  | 640     | < | 70/13.6     | 5.09/20.3  | 2.00/22.7 |  | 8       | 130/8  | 373       | 519 | 216.8     |
| Devco               | Sydney      | No. 26        | 2        | 690/1  | 590     | < | 60/15.9     | 3.02/4.0   | 2.74/-    |  | 5       | 180/2  | 909       | 100 | 66.2      |
| Devco               | Sydney      | (Mixture)     | 14       | 400/14 | 300     | < | 100/64.1    | 14.8/26.9  | 2.71/14.4 |  | 13      | 372/14 | 510       | 515 | 1 054     |
| Devco               | Sydney      | Prince        | 20       | 500/18 | 080     |   | 93.7/93.0   | 16.8/41.1  | 6.80/31.6 |  | 29      | 200/29 | 320       | 1   | 000/630.0 |
| NEW BRUNSWICK       |             |               |          |        |         |   |             |            |           |  |         |        |           |     |           |
| N.B. Electric Power | Minto       | Minto         | 10       | 100/9  | 382     | < | 100/43.1    | 12.15/25.6 | 3.81/26.4 |  | 47      | 300/49 | 190       | 333 | 396.2     |
| N.B. Coal           | Minto       | Minto         | 10       | 700/9  | 083     | < | 100/33.9    | 6.84/20.2  | 10.6/32.7 |  | 77      | 100/89 | 960       | 175 | 423.4     |
| SASKATCHEWAN        |             |               |          |        |         |   |             |            |           |  |         |        |           |     |           |
| Manitoba Power      | Estevan     | Estevan       | 12       | 100/11 | 440     |   | 1 090/841.4 | < 4.0/7.3  | 1.56/5.5  |  | 2       | 950/1  | 005       | 1   | 826/2 426 |
| M&S Coal            | Estevan     | Bienfait      | 11       | 800/13 | 930     |   | 1 120/1 213 | < 4.0/7.6  | < 0.4/3.8 |  | 3       | 090/3  | 297       | 1   | 170/2 132 |
| M&S Coal            | Estevan     | Boundary Dam  | 14       | 000/16 | 440     |   | 832/1 086   | < 4.0/9.9  | 1.72/-    |  | 3       | 380/3  | 854       | 1   | 730/2 682 |
| Sask. Power Corp.   | Estevan     | Boundary Dam  | 8        | 570/15 | 180     |   | 594/755.0   | 16.22/20.3 | 5.59/3.9  |  | 3       | 990/4  | 031       | 2   | 870/2 622 |
| Sask. Power Corp.   | Estevan     | Queen Eliz.   | 10       | 500/10 | 150     |   | 462/430.8   | < 4.0/4.0  | 0.86/-    |  | 3       | 890/4  | 442       | 2   | 400/976.5 |
| Manalta             | Estevan     | Klimax        | 14       | 000/14 | 710     |   | 1 190/253.9 | < 4.0/6.0  | 0.47/-    |  | 3       | 610/4  | 338       | 3   | 720/2 717 |
| Poplar River        | Core Sample | Exploratory   | 22       | 400/21 | 640     |   | 675/543.0   | < 5.0/14.8 | 1.16/-    |  | 5       | 530/6  | 598       | 5   | 590/5 124 |
| Poplar River        | Core Sample | Exploratory   | 18       | 500/15 | 910     |   | 413/372.9   | < 4.0/10.5 | 0.48/-    |  | 4       | 700/4  | 675       | 4   | 410/4 334 |

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company            | Field         | Mine                | Aluminum      | Barium      | Chromium   | Cobalt    | Iron          | Magnesium     |
|--------------------|---------------|---------------------|---------------|-------------|------------|-----------|---------------|---------------|
|                    |               |                     | NAA/PES       | NAA/PES     | NAA/PES    | NAA/PES   | NAA/PES       | NAA/PES       |
| ALBERTA            |               |                     |               |             |            |           |               |               |
| Manalta            | Sheerness     | Roselyn             | 13 200/17 760 | 166/278.6   | < 3.0/5.6  | 0.84/-    | 4 740/4 347   | 1 270/1 440   |
| McIntyre           | Grande Cache  | McIntyre            | 10 800/11 160 | 301/328.4   | < 3.0/8.6  | 2.03/-    | 2 070/1 879   | 614/265.1     |
| McIntyre           | Grande Cache  | McIntyre            | 12 100/11 480 | 363/400.5   | < 5.0/10.4 | 1.53/-    | 2 520/432.6   | 1 330/243.8   |
| Luscar Coal        | Castor        | Diplomat            | 7 640/7 078   | 308/412.5   | < 3.0/1.9  | 0.69/7.6  | 2 700/2 438   | 1 690/815.4   |
| Manalta            | Castor        | Vesta               | 10 100/11 280 | 558/508.7   | < 3.0/0.9  | 0.52/-    | 2 520/3 171   | < 1 000/482.4 |
| Century Coals      | Drumheller    | Atlas               | 12 800/13 530 | 395/568.9   | < 3.0/3.0  | 0.42/-    | 3 690/3 832   | 537/746.7     |
| Manalta            | Pembina       | Highvale            | 20 700/20 930 | 617/589.9   | < 3.0/4.4  | 1.39/-    | 2 760/3 418   | 1 250/834.5   |
| Manalta            | Pembina       | Whitewood           | 15 300/15 950 | 264/415.0   | 2.29/7.3   | 1.43/-    | 4 570/4 996   | 1 470/1 542   |
| Sundance Mines     | Edmonton      | Sundance            | 14 700/15 420 | 570/597.5   | 3.01/4.8   | 2.15/-    | 5 070/5 250   | 3 050/730.5   |
| Imperial Oil       | Edmonton      | Judy Creek          | 20 500/29 050 | 623/528.6   | < 5.0/16.0 | 2.41/16.2 | 4 350/4 547   | 903/1 065     |
| Coleman Collieries | Crowsnest     | Vicary Creek        | 16 100/14 320 | 719/727.3   | 9.21/7.9   | 2.27/10.2 | 1 850/1 795   | 6 92/598.0    |
| Coleman Collieries | Crowsnest     | Tent Mountain       | 13 000/18 660 | 282/557.9   | < 7.0/13.0 | 1.73/-    | 2 140/1 913   | 2 300/700.7   |
| Cardinal River     | Mountain Park | Cardinal river      | 7 520/11 450  | 473/473.9   | 5.65/6.4   | 0.78/-    | 283/2 318     | 2 416/923.6   |
| BRITISH COLUMBIA   |               |                     |               |             |            |           |               |               |
| B.C. Hydro         | Ashcroft      | Hat Creek           | 61 800/77 240 | 235/343.1   | 37.3/62.6  | 9.85/14.2 | 16 400/20 560 | 3 280/3 933   |
| B.C. Hydro         | Ashcroft      | Hat Creek*          | 29 600/32 000 | 129/115.8   | 30.5/42.0  | 8.56/11.5 | 9 810/9 989   | 1 560/2 413   |
| Tulameen           | Tulameen      | Tulameen            | 11 700/12 480 | 97.4/88.5   | 28.4/35.8  | 3.90/22.1 | 9 610/10 460  | 242/561.4     |
| B.P. Canada        | Chetwynd      | Sukunka             | 15 700/14 470 | 1 160/925.5 | 22.8/22.5  | 2.22/2.8  | 3 610/3 926   | 1 040/1 249   |
| Denison Coal       | E. Kootenay   | Denison             | 8 600/8 460   | < 60/697.2  | 9.59/18.5  | 2.57/12.4 | 3 550/4 568   | < 1 000/1 249 |
| Byron Creek        | E. Kootenay   | Byron Creek         | 14 000/25 430 | 674/702.9   | < 5.0/8.2  | 0.65/-    | 2 380/2 708   | 4 860/1 354   |
| Kaiser Resources   | E. Kootenay   | Kaiser (Seam No. 7) | 17 000/14 050 | 386/324.8   | 6.67/11.3  | 1.77/-    | 3 610/3 769   | 100/157.9     |
| Kaiser Resources   | E. Kootenay   | Elk View            | 18 900/24 520 | 200/104.4   | 4.06/11.9  | 1.49/-    | 540/803.6     | 585/373.6     |
| Kaiser Resources   | E. Kootenay   | Elk View*           | 15 900/13 380 | 200/77.1    | 2.56/8.0   | 0.96/-    | 1 490/1 499   | 515/247.7     |
| Fording Coal       | E. Kootenay   | Fording             | 15 400/14 320 | 200/71.8    | 13.0/11.0  | 2.18/-    | 2 060/2 087   | < 1 000/262.1 |

\* Clean coal samples



TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company             | Field       | Mine          | Manganese  |     | Potassium    |     | Sodium      |     | Strontium  |     | Thorium  |     | Titanium    |     | Vanadium   |     |
|---------------------|-------------|---------------|------------|-----|--------------|-----|-------------|-----|------------|-----|----------|-----|-------------|-----|------------|-----|
|                     |             |               | NAA/PES    | PES | NAA/PES      | PES | NAA/PES     | PES | NAA/PES    | PES | NAA/PES  | PES | NAA/PES     | PES | NAA/PES    | PES |
| NOVA SCOTIA         |             |               |            |     |              |     |             |     |            |     |          |     |             |     |            |     |
| River Herbert       | Joggins     | River Herbert | 219/208.4  |     | 10 900/9 163 |     | 1 390/-     |     | < 500/73.7 |     | 2.95/4.7 |     | 1 160/1 005 |     | 49.1/55.4  |     |
| Thorburn            | Pictou      | Acadia        | 132/102.6  |     | 7 350/7 156  |     | 517/1 806   |     | <100/121.6 |     | 3.62/1.9 |     | 2 920/901.8 |     | 58.0/59.7  |     |
| Devco               | Sydney      | Lingan        | 96.9/102.5 |     | 360/290.3    |     | 143/-       |     | < 70/10.4  |     | 0.30/2.7 |     | 400/127.0   |     | 3.88/5.3   |     |
| Devco               | Sydney      | No. 26        | 58.5/33.6  |     | < 100/72.3   |     | 45.0/361.4  |     | < 70/4.8   |     | 0.20/-   |     | 340/77.3    |     | 5.34/3.3   |     |
| Devco               | Sydney      | Prince        | 51.3/49.2  |     | 3 150/3 318  |     | 355/-       |     | 174/130.8  |     | 2.03/6.1 |     | 644/677.7   |     | 9.13/28.3  |     |
| NEW BRUNSWICK       |             |               |            |     |              |     |             |     |            |     |          |     |             |     |            |     |
| N.B. Electric Power | Minto       | Minto         | 378/335.2  |     | < 100/1 694  |     | 389/-       |     | < 100/43.8 |     | 1.16/3.6 |     | 1 670/519.2 |     | 26.98/21.0 |     |
| N.B. Coal           | Minto       | Minto         | 526/454.2  |     | < 200/1 068  |     | 1 92/-      |     | < 100/45.9 |     | 1.10/2.9 |     | 1 270/510.0 |     | 31.6/25.8  |     |
| SASKATCHEWAN        |             |               |            |     |              |     |             |     |            |     |          |     |             |     |            |     |
| Manitoba Power      | Estevan     | Estevan       | 47.5/33.9  |     | 627/805.7    |     | 4 090/-     |     | 414/380.9  |     | 2.14/6.4 |     | 508/564.9   |     | 7.56/9.0   |     |
| M&S Coal            | Estevan     | Bienfait      | 24.3/18.8  |     | < 200/691.6  |     | 6 820/-     |     | 170/401.7  |     | 3.23/6.6 |     | 1 730/891.5 |     | 5.01/9.0   |     |
| M&S Coal            | Estevan     | Boundary Dam  | 26.3/19.8  |     | < 200/797.8  |     | 6 740/7 209 |     | 162/456.6  |     | 2.70/-   |     | 1 650/747.8 |     | 7.93/10.9  |     |
| Sask. Power Corp.   | Estevan     | Boundary Dam  | 34.9/27.5  |     | 1 770/1 459  |     | 7 560/8 279 |     | 240/426.8  |     | 1.99/1.0 |     | 421/592.4   |     | 22.4/31.7  |     |
| Sask. Power Corp.   | Estevan     | Queen Eliz.   | 106/110.1  |     | 822/813.8    |     | 1 820/-     |     | <400/201.1 |     | 1.85/1.9 |     | 162/282.4   |     | 4.65/5.1   |     |
| Manalta             | Estevan     | Klimax        | 48.2/38.9  |     | < 700/75.0   |     | 4 660/5 435 |     | 681/551.9  |     | 3.68/2.8 |     | 626/874.3   |     | 4.74/7.5   |     |
| Poplar River        | Core Sample | Exploratory   | 125/112.0  |     | 3 280/2 988  |     | 1 090/2 203 |     | <600/259.5 |     | 3.36/2.9 |     | 681/688.6   |     | 17.2/20.1  |     |
| Poplar River        | Core Sample | Exploratory   | 127/98.6   |     | 2 370/1 972  |     | 994/1 855   |     | <600/217.7 |     | 3.92/2.9 |     | 678/528.1   |     | 17.5/1.52  |     |

TABLE 6 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND PLASMA EMISSION SPECTROMETRY (cont'd.)

| Company                 | Field         | Mine                | Manganese  | Potassium   | Sodium      | Strontium   | Thorium  | Titanium    | Vanadium   |
|-------------------------|---------------|---------------------|------------|-------------|-------------|-------------|----------|-------------|------------|
|                         |               |                     | NAA/PES    | NAA/PES     | NAA/PES     | NAA/PES     | NAA/PES  | NAA/PES     | NAA/PES    |
| <b>ALBERTA</b>          |               |                     |            |             |             |             |          |             |            |
| Manalta                 | Sheerness     | Roselyn             | 113/154.2  | < 100/1 440 | 1 150/1 776 | < 100/211.3 | 1.82/1.9 | 500/388.9   | 4.72/6.3   |
| McIntyre                | Grande Cache  | McIntyre            | 10.0/5.0   | 786/241.9   | 570/837.2   | 88.9/142.3  | 1.51/-   | 1 550/654.9 | 26.3/26.9  |
| McIntyre                | Grande Cache  | McIntyre            | 11.5/3.8   | 554/318.4   | 9 150/670.2 | < 500/163.4 | 1.55/-   | 654/628.4   | 26.9/31.1  |
| Luscar Coal             | Castor        | Diplomat            | 26.9/25.1  | 585/743.0   | 1 370/-     | 217/254.3   | 1.48/6.7 | 220/194.3   | 2.83/3.0   |
| Manalta                 | Castor        | Vesta               | 36.2/46.8  | 1 040/846.2 | 3 150/3 891 | 230/374.5   | 2.11/-   | 161/216.9   | 0.94/2.8   |
| Century Coals           | Drumbeller    | Atlas               | 76.5/102.7 | 1 030/1 007 | 3 830/-     | 374/355.6   | 2.88/-   | 213/288.4   | 2.11/4.3   |
| Manalta                 | Pembina       | Highvale            | 56.8/97.3  | 352/362.1   | 2 470/3 709 | < 500/145.7 | 2.96/3.5 | 451/538.7   | 4.09/6.5   |
| Manalta                 | Pembina       | Whitewood           | 144/154.2  | 719/660.9   | 228/969.2   | < 400/62.0  | 2.72/3.5 | 556/500.5   | 9.47/9.1   |
| Sundance Mines          | Edmonton      | Sundance            | 82.5/86.8  | 360/266.2   | 3 180/3 212 | < 500/144.1 | 2.55/1.8 | 403/509.4   | 9.29/10.5  |
| Imperial Oil            | Edmonton      | Judy Creek          | 141/151.6  | 1 460/775.8 | 1 910/-     | < 600/133.5 | 6.17/9.0 | 942/1001    | 10.62/15.2 |
| Coleman Collieries      | Crowsnest     | Vicary Creek        | 21.7/12.1  | < 200/734.7 | 300/-       | 170/200.0   | 2.93/6.5 | 2 520/1 116 | 33.8/34.9  |
| Coleman Collieries      | Crowsnest     | Tent Mountain       | 20.1/10.4  | 584/307.9   | 241/373.2   | < 500/223.9 | 4.82/-   | 989/1 316   | 62.9/44.4  |
| Cardinal River          | Mountain Park | Cardinal River      | 15.1/6.4   | 489/204.8   | 1 000/-     | < 400/128.5 | 2.22/0.9 | 420/530.7   | 11.8/14.9  |
| <b>BRITISH COLUMBIA</b> |               |                     |            |             |             |             |          |             |            |
| B.C. Hydro              | Ashcroft      | Hat Creek           | 172/177.2  | 3 060/3 412 | 680/2 654   | < 200/124.1 | 2.54/3.8 | 5.5/3 080   | 93.5/125.1 |
| B.C. Hydro              | Ashcroft      | Hat Creek*          | 41.2/29.4  | < 100/1 538 | 787/1 945   | < 90/67.6   | 1.45/-   | 3 010/1 768 | 108/128.2  |
| Tulameen                | Tulameen      | Tulameen            | 53.5/54.3  | 1 750/2 774 | 165/0       | < 90/23.1   | 2.19/2.9 | 1 600/838.8 | 34.3/38.9  |
| B.P. Canada             | Chetwynd      | Sukunka             | 18.4/7.7   | 3 370/3 250 | 786/1 409   | < 600/119.3 | 1.79/-   | 688/741.1   | 68.8/66.6  |
| Denison Coal            | E. Kootenay   | Denison             | 10.7/7.5   | < 200/419.6 | 448/-       | 65.5/100.1  | 1.56/1.9 | 983/477.8   | 23.4/24.6  |
| Byron Creek             | E. Kootenay   | Byron Creek         | 32.7/15.9  | 612/359.3   | 810/1 290   | < 600/234.0 | 1.26/-   | 1 110/1 621 | 18.6/29.2  |
| Kaiser Resources        | E. Kootenay   | Kaiser (Seam No. 7) | 19.5/9.6   | < 100/428.9 | 84.7/365.0  | < 70/130.5  | 1.62/-   | 2 520/756.4 | 46.4/40.0  |
| Kaiser Resources        | E. Kootenay   | Elk View            | 13.4/4.5   | 1 160/785.4 | 42.8/287.4  | < 500/26.1  | 1.35/-   | 945/1 226   | 23.8/27.1  |
| Kaiser Resources        | E. Kootenay   | Elk View*           | 20.8/-     | 460/161.3   | 44.8/-      | < 500/22.7  | 1.45/-   | 733/780     | 19.4/22.8  |
| Fording Coal            | E. Kootenay   | Fording             | 23.5/16.0  | 1 165/589.7 | 57.8/-      | < 500/36.2  | 1.97/-   | 1 040/864.8 | 39.4/38.8  |

\* Clean coal samples

TABLE 7 COMPARISON OF TRACE ELEMENT CONCENTRATIONS (IN PPM) AS DETERMINED BY PLASMA EMISSION SPECTROMETRY AND ATOMIC ABSORPTION SPECTROMETRY

| Company            | Field        | Mine                | Copper    |           | Iron    |         | Lead      |             | Manganese |         | Zinc    |         |
|--------------------|--------------|---------------------|-----------|-----------|---------|---------|-----------|-------------|-----------|---------|---------|---------|
|                    |              |                     | PES/AAS   | PES/AAS   | PES/AAS | PES/AAS | PES/AAS   | PES/AAS     | PES/AAS   | PES/AAS | PES/AAS | PES/AAS |
| NOVA SCOTIA        |              |                     |           |           |         |         |           |             |           |         |         |         |
| Devco              | Sydney       | No. 26              | 3.6/6.7   | 2         | 929/3   | 250     | 1.8/0.9   | 33.6/61.8   | 5.4/10.5  |         |         |         |
| SASKATCHEWAN       |              |                     |           |           |         |         |           |             |           |         |         |         |
| Poplar River       | Core Sample  | Exploratory         | 14.5/18.6 | 4         | 675/5   | 749     | 17.6/20.8 | 98.6/107.4  | 22.5/19.5 |         |         |         |
| ALBERTA            |              |                     |           |           |         |         |           |             |           |         |         |         |
| McIntyre           | Grande Cache | McIntyre            | 9.8/10.9  | 4         | 32.6/1  | 885     | 5.0/9.2   | 3.8/5.9     | 50.3/44.4 |         |         |         |
| Coleman Collieries | Crowsnest    | Tent Mountain       | 16.2/17.7 | 1         | 913/1   | 987     | 11.2/13.9 | 10.4/12.1   | 53.2/28.9 |         |         |         |
| BRITISH COLUMBIA   |              |                     |           |           |         |         |           |             |           |         |         |         |
| B.C. Hydro         | Ashcroft     | Hat Creek           | 61.4/68.2 | 20        | 560/21  | 133     | 3.8/19.9  | 177.2/183.9 | 58.8/56.9 |         |         |         |
| B.C. Hydro         | Ashcroft     | Hat Creek*          | 58.7/62.8 | 9         | 989/10  | 784     | 7.1/12.4  | 29.4/31.8   | 35.4/56.9 |         |         |         |
| B.P. Canada        | Chetwynd     | Sukunka             | 8.8/9.4   | 3         | 926/4   | 245     | 5.6/8.4   | 7.7/8.5     | 29.1/28.2 |         |         |         |
| Byron Creek        | E. Kootenay  | Byron Creek         | 12.5/13.8 | 2         | 708/2   | 929     | 5.5/11.0  | 15.9/19.34  | 10.1/10.1 |         |         |         |
| Kaiser Resources   | E. Kootenay  | Kaiser (Seam No. 7) | 15.1/15.5 | 3         | 769/3   | 832     | 2.7/6.3   | 9.6/11.0    | 18.2/15.6 |         |         |         |
| Kaiser Resources   | E. Kootenay  | Elk View            | 9.0/8.62  | 803.6/729 |         |         | 5.7/5.7   | 4.5/4.8     | 88.1/14.4 |         |         |         |

\* Clean coal samples





## APPENDICES





## APPENDIX 1

### SAMPLE PREPARATION AND DISSOLUTION TECHNIQUES

Homogeneous coal samples for analysis by AAS and PES were prepared by first thoroughly mixing portions of the top, middle, and bottom of the bulk coal samples. The prepared coal samples were dried overnight in a desiccator (the weight loss on drying was negligible; 0.06 to 1.1%) and then weighed in porcelain dishes and placed in a cold muffle furnace. The temperature of the furnace was raised, in 50 C degree steps, to 750 degrees C over two hours and maintained at this temperature for 24 hours.

Siliceous material in the ash produced by this high temperature ashing procedure was removed by the addition of hydrofluoric acid (HF) followed by slow evaporation to dryness. The residues from the HF treatment were then dissolved using one of the methods listed below. The coals corresponding to the identification numbers are given in Table 8.

#### Group 1

The residue was dissolved in a mixture of 5 ml  $\text{HNO}_3$  and 3 ml  $\text{HCl}$  and made up to 100 ml with water.

| Nova Scotia | Saskatchewan | Alberta | British Columbia |
|-------------|--------------|---------|------------------|
| 2           | 15           | 18, 27  | 34, 35, 36, 37   |

#### Group 2

The residue was dissolved in 5 ml  $\text{HNO}_3$  and made up to 100 ml with water.

| Nova Scotia | Saskatchewan   | Alberta                   | British Columbia |
|-------------|----------------|---------------------------|------------------|
| 4           | 10, 11, 13, 14 | 16, 17, 20,<br>22, 23, 26 | 38               |

#### Group 3A

The residue was treated with a mixture of 5 ml  $\text{HNO}_3$  and 3 ml  $\text{HCl}$ . Undissolved material was filtered and fused with a mixture of lithium and sodium tetraborates. The fused material was dissolved in the original filtrate and made up to 100 ml with water.

| Nova Scotia | Alberta | British Columbia |
|-------------|---------|------------------|
| 1           | 25      | 31, 33           |

Group 3B

The same procedure was followed as for Group 3A, except that nitric acid rather than aqua regia was used in the first dissolution step.

Nova Scotia

New Brunswick

3, 5

6, 7

Group 4

The residue was treated with 5 ml  $\text{HNO}_3$ . A very small amount of undissolved material remained; it was filtered, dissolved in 1 ml of 40% NaOH solution, acidified and then added to the original filtrate which was made up to 100 ml with water.

Saskatchewan

Alberta

8, 9, 12

19, 21, 26, 28

TABLE 8 COAL IDENTIFICATION NUMBERS FOR SAMPLE DISSOLUTION TECHNIQUES

| Number               | Company             | Field       | Mine          | Number                  | Company            | Field         | Mine                |
|----------------------|---------------------|-------------|---------------|-------------------------|--------------------|---------------|---------------------|
| <b>NOVA SCOTIA</b>   |                     |             |               | <b>ALBERTA</b>          |                    |               |                     |
| 1                    | River Herbert       | Joggins     | River Herbert | 16                      | Manalta            | Sheerness     | Roselyn             |
|                      |                     |             |               | 17                      | McIntyre           | Grande Cache  | McIntyre            |
|                      |                     |             |               | 18                      | McIntyre           | Grande Cache  | McIntyre            |
| 2                    | Thorburn            | Pictou      | Acadia        | 19                      | Luscar Coal        | Castor        | Diplomat            |
| 3                    | Devco               | Sydney      | Lingan        | 20                      | Manalta            | Castor        | Vesta               |
| 4                    | Devco               | Sydney      | No. 26        | 21                      | Century Coals      | Drumheller    | Atlas               |
|                      |                     |             |               | 22                      | Manalta            | Pembina       | Highvale            |
| 5                    | Devco               | Sydney      | Prince        | 23                      | Manalta            | Pembina       | Whitewood           |
|                      |                     |             |               | 24                      | Sundance Mines     | Edmonton      | Sundance            |
| <b>NEW BRUNSWICK</b> |                     |             |               | 25                      | Imperial Oil       | Edmonton      | Judy Creek          |
| 6                    | N.B. Electric Power | Minto       | Minto         | 26                      | Coleman Collieries | Crowsnest     | Vicary Creek        |
| 7                    | N.B. Coal           | Minto       | Minto         | 27                      | Coleman Collieries | Crowsnest     | Tent Mountain       |
|                      |                     |             |               | 28                      | Cardinal River     | Mountain Park | Cardinal River      |
| <b>SASKATCHEWAN</b>  |                     |             |               | <b>BRITISH COLUMBIA</b> |                    |               |                     |
| 8                    | Manitoba Power      | Estevan     | Estevan       | 29                      | B.C. Hydro         | Ashcroft      | Hat Creek           |
| 9                    | M&S Coal            | Estevan     | Bienfait      | 30                      | B.C. Hydro         | Ashcroft      | Hat Creek*          |
| 10                   | M&S Coal            | Estevan     | Boundary Dam  | 31                      | B.P. Canada        | Tulameen      | Tulameen            |
| 11                   | Sask. Power Corp.   | Estevan     | Boundary Dam  | 32                      | B.P. Canada        | Chetwynd      | Sukunka             |
| 12                   | Sask. Power Corp.   | Estevan     | Queen Eliz.   | 33                      | Denison Coal       | E. Kootenay   | Denison             |
| 13                   | Manalta             | Estevan     | Klimax        | 34                      | Byron Creek Co.    | E. Kootenay   | Byron Creek         |
| 14                   | Poplar River        | Core Sample | Exploratory   | 35                      | Kaiser Resources   | E. Kootenay   | Kaiser (Seam No. 7) |
| 15                   | Poplar River        | Core Sample | Exploratory   | 36                      | Kaiser Resources   | E. Kootenay   | Elk View            |
|                      |                     |             |               | 37                      | Kaiser Resources   | E. Kootenay   | Elk View*           |
|                      |                     |             |               | 38                      | Fording Coal       | E. Kootenay   | Fording             |

\* Clean coal samples





## APPENDIX 2

### DETERMINATION OF TRACE ELEMENTS IN NBS STANDARD REFERENCE COALS

To provide quality control assurance for the analytical data obtained in this study, the trace element concentrations in two National Bureau of Standards reference coals (NBS 1632 and 1632a) were determined by the same measurement techniques (NAA, PES and AAS) employed for the 38 coal samples. The results of these determinations are given in Tables 9-12, together with the certified and informational trace element concentrations reported by NBS.

It will be seen from Tables 9 and 10 that the NAA results are generally in good agreement with the NBS values. An exception is the NAA result for manganese (Table 10), which is significantly higher than the NBS certified value. However, this discrepancy is not unexpected because the 847-keV gamma line from Mn-56 (the isotope measured in the instrumental NAA determination of manganese) cannot be fully resolved by the Ge(Li) gamma-ray detector from the 844-keV gamma line from Mg-27 (produced by the Al-27 (n,p) Mg-27 reaction). This spectral interference gives a positive bias to the manganese concentration measurement.

The concentrations of trace elements, as determined by atomic absorption spectrometry, in the standard reference coal NBS 1632 (Table 11) are in excellent agreement with the NBS certified values, with only the results for chromium and nickel falling somewhat outside the given confidence limits. The plasma emission spectrometry results (Table 12) were, in general, less accurate than those obtained by AAS and NAA, and PES would therefore probably not be the method of choice for those elements that can be determined by the other methods.

From the results given in Tables 9-12, it would appear that for trace element determinations in coal where speed, economy, and reasonable accuracy are required, that NAA is the most advantageous analytical method to use, bearing in mind, of course, that not all elements can be determined by this method.

TABLE 9 RESULTS OF NEUTRON ACTIVATION ANALYSIS DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632

| Element   | NBS Value <sup>1</sup><br>Concentration ( $\mu\text{g/g}$ ) | NAA Result <sup>2</sup><br>Concentration ( $\mu\text{g/g}$ ) |
|-----------|-------------------------------------------------------------|--------------------------------------------------------------|
| Arsenic   | $5.9 \pm 0.6$                                               | $5.34 \pm 0.6$                                               |
| Chromium  | $20.2 \pm 0.5$                                              | $21.2 \pm 3.4$                                               |
| Cobalt    | (6)                                                         | $5.51 \pm 0.9$                                               |
| Iron      | $8\,700 \pm 300$                                            | $8\,590 \pm 950$                                             |
| Manganese | $40 \pm 3$                                                  | $53.6 \pm 11$                                                |
| Selenium  | $2.9 \pm 0.3$                                               | <6                                                           |
| Tellurium | (<0.1)                                                      | <2.0                                                         |
| Thorium   | (3.0)                                                       | $2.61 \pm 0.3$                                               |
| Uranium   | $1.4 \pm 0.1$                                               | $1.34 \pm 0.1$                                               |
| Vanadium  | $35 \pm 3$                                                  | $33.1 \pm 4$                                                 |

<sup>1</sup> Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

<sup>2</sup> Errors in NAA determinations are the sum of a 5% sample handling error and a one-standard-deviation counting-statistics error.



TABLE 10 RESULTS OF NEUTRON ACTIVATION ANALYSIS DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632a

| Element   | NBS Value <sup>1</sup><br>Concentration ( $\mu\text{g/g}$ ) | NAA Result <sup>2</sup><br>Concentration ( $\mu\text{g/g}$ ) |
|-----------|-------------------------------------------------------------|--------------------------------------------------------------|
| Aluminum  | (30 700)                                                    | $33\,800 \pm 2\,000$                                         |
| Antimony  | (0.58)                                                      | $<0.7$                                                       |
| Arsenic   | $9.3 \pm 1$                                                 | $7.15 \pm 0.7$                                               |
| Cerium    | (30)                                                        | $21.7 \pm 3$                                                 |
| Chromium  | $34.4 \pm 1.5$                                              | $31.3 \pm 4$                                                 |
| Cobalt    | (6.8)                                                       | $5.83 \pm 0.9$                                               |
| Europium  | (0.54)                                                      | $0.71 \pm 0.2$                                               |
| Hafnium   | (1.6)                                                       | $1.44 \pm 0.3$                                               |
| Iron      | $11\,100 \pm 200$                                           | $11\,200 \pm 1\,000$                                         |
| Manganese | $28 \pm 2$                                                  | $46.9 \pm 12$                                                |
| Scandium  | (6.3)                                                       | $5.82 \pm 0.4$                                               |
| Selenium  | $2.6 \pm 0.7$                                               | $<6.0$                                                       |
| Thorium   | $4.5 \pm 0.1$                                               | $3.8 \pm 0.5$                                                |
| Titanium  | (1 750)                                                     | $1\,770 \pm 270$                                             |
| Uranium   | $1.28 \pm 0.02$                                             | $0.87 \pm 0.09$                                              |
| Vanadium  | $44 \pm 3$                                                  | $42.3 \pm 5$                                                 |

<sup>1</sup> Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

<sup>2</sup> Errors in NAA determinations are the sum of a 5% sample handling error and a one-standard-deviation counting-statistics error.

TABLE 11 RESULTS OF ATOMIC ABSORPTION SPECTROMETRY DETERMINATION OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL BUREAU OF STANDARDS REFERENCE COAL, NBS 1632

| Element   | NBS Value <sup>1</sup><br>Concentration ( $\mu\text{g/g}$ ) | AAS Result<br>Concentration ( $\mu\text{g/g}$ ) |
|-----------|-------------------------------------------------------------|-------------------------------------------------|
| Arsenic   | $5.9 \pm 0.6$                                               | 5.7                                             |
| Cadmium   | $0.19 \pm 0.03$                                             | 0.19                                            |
| Chromium  | $20.2 \pm 0.5$                                              | 19                                              |
| Copper    | $18 \pm 2$                                                  | 18.3                                            |
| Iron      | $8\,700 \pm 300$                                            | 8\,650                                          |
| Lead      | $30 \pm 9$                                                  | 33.2                                            |
| Manganese | $40 \pm 3$                                                  | 40.8                                            |
| Nickel    | $15 \pm 1$                                                  | 19                                              |
| Vanadium  | $35 \pm 3$                                                  | 32                                              |
| Zinc      | $37 \pm 4$                                                  | 36.8                                            |

<sup>1</sup> Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.

TABLE 12      RESULTS OF PLASMA EMISSION SPECTROMETRY DETERMINATION  
OF THE CONCENTRATION OF TRACE ELEMENTS IN NATIONAL  
BUREAU OF STANDARDS REFERENCE COAL, NBS 1632

| Element   | NBS Value <sup>1</sup><br>Concentration ( $\mu\text{g/g}$ ) | PES Result<br>Concentration ( $\mu\text{g/g}$ ) |
|-----------|-------------------------------------------------------------|-------------------------------------------------|
| Chromium  | $20.2 \pm 0.5$                                              | 17                                              |
| Copper    | $18 \pm 2$                                                  | 13.8                                            |
| Iron      | $8\,700 \pm 300$                                            | 8\,210                                          |
| Lead      | $30 \pm 9$                                                  | 23                                              |
| Manganese | $40 \pm 3$                                                  | 39.7                                            |
| Vanadium  | $35 \pm 3$                                                  | 23.7                                            |

<sup>1</sup> Concentrations in parentheses are reported by NBS for information purposes only and are not certified values. Other concentrations are certified values at the 95% or greater confidence limit.









